

A. SPECIFICATION

This appendix contains Specification Section 130541, Seismic Restraint Requirements for Nonstructural Components. This Section is intended to aggregate requirements for seismic restraint of nonstructural components and should be cross referenced from each specification section that includes nonstructural components requiring seismic protection. This specification has been written to address nonstructural components for which the Contractor is assigned responsibility for both design and construction. Items that have been explicitly designed by the design team and included on the drawings may be removed from this section, or the relevant section may be modified to indicate that the Contractor is required to furnish and install restraints only.

The specification is intended to be used in conjunction with the responsibility matrices provided in Appendix B to facilitate compliance with nonstructural performance objectives.

The Section is provided as a Microsoft Word file (.doc) file for download here and should be customized for use in projects.

SECTION 130541

SEISMIC RESTRAINT REQUIREMENTS FOR NONSTRUCTURAL COMPONENTS

[NOTE TO SPECIFIER: This section is intended to aggregate requirements for seismic restraint of nonstructural components. It should be cross referenced from each specification section that includes nonstructural components requiring seismic protection. This specification has been written to address nonstructural components for which the Contractor is assigned responsibility for both design and construction. Items that have been explicitly designed by the design team and included on the drawings may be removed from this section, or the relevant section may be modified to indicate that the Contractor is required to furnish and install restraints only.]

PART 1 - GENERAL

1.1 DESCRIPTION

- A. Provide seismic restraint of nonstructural components to withstand seismic forces and seismic deformations without displacing or overturning. For designated nonstructural components, provide installations capable of providing post-earthquake functionality.
- B. Work in this section includes furnishing and installing complete seismic restraint systems. Work in this section may also include the seismic restraint design and/or equipment/product certifications to be submitted for review by the registered design professional.

1.2 SCOPE

- A. The architectural, mechanical, electrical, and plumbing components and systems identified on the following Responsibility Matrix shall be designed and constructed for seismic demands.

[NOTE TO SPECIFIER: Insert the Responsibility Matrix appropriate for the project Seismic Design Category (see Section 1.3A). Explicitly list those components requiring seismic design, specify each component importance factor, I_p , identify the parties responsible for design, preparation of shop drawings and seismic calculations and indicate which components require Special Seismic Certification.]

Figure A-1 Screenshot showing Specification Section 130541, Seismic Restraint Requirements for Nonstructural Components.

B. RESPONSIBILITY MATRIX

This appendix contains responsibility matrix templates for the seismic protection of nonstructural components. The templates are to be used for assigning responsibility for design, construction, and inspection of nonstructural installations governed by ASCE/SEI 7-10. Three separate templates are provided for Seismic Design Categories B, C, and D/E/F, respectively. In addition, a Basic Form is provided for general use. The matrices are intended to be used in conjunction with the construction specification provided in Appendix A.

The matrices are provided as a Microsoft Excel file (.xls) file for download here and should be customized for use in projects.

A	B	C	D	E	F	G	H	I	J	
1	RESPONSIBILITY MATRIX									
2	FOR THE SEISMIC PROTECTION OF NONSTRUCTURAL COMPONENTS									
3	SEISMIC DESIGN CATEGORY B									
4										
5	NONSTRUCTURAL COMPONENTS									
6	General categories shown with sample entries (in blue); insert line items for project specific components		Is Seismic Design Required? (yes/exempt)	Component Importance Factor, Ip (See Note 1)	Party Responsible for Design of Seismic Details (See Note 2)	Party Responsible for Preparation of Seismic Shop Drawings (See Note 2)	Party Responsible for Preparation of Seismic Calculations (See Note 2)	Is Special Seismic Certification Required? (See Note 3)	Is seismic design being handled as a Deferred Approval?	Party Responsible for Site Inspection of Installed Component/System
7	ITEM	DESIGNATED SEISMIC SYSTEMS (See Note 1)	Exempt	Ip=1.5				No		
8	S.1	Component required to function for life-safety purposes after an earthquake, including fire protection sprinkler systems and egress stairways. (per 13.1.3.1)	Exempt per 13.1.4.2							
9	S.2	Component conveys, supports or contains toxic or explosive substances. (per	Exempt per 13.1.4.2							
10	S.3	Component in or attached to Risk Category IV structure and is needed for continued operation of the facility or its failure could impair the continued function of other components.	NA							
11	Note	Systems in Seismic Design Category B (other exemptions may apply, see ASCE 7-10)	Exempt							
12		Mechanical and electrical components in Seismic Design Category B are exempt from the requirements of Chapter 13 of ASCE 7.	Exempt per 13.1.4							
13										
14										
15	ITEM	STANDARD NONSTRUCTURAL COMPONENTS		Ip=1.0 (UON)						
16		ARCHITECTURAL COMPONENTS								
17										
18	A.1	Exterior Wall Components	Exempt							
19	A.2	Interior Partitions	Exempt							
20	A.3	Ceilings	Exempt							
21										
22										
23										
24										

Figure B-1 Screenshot showing Responsibility Matrix for the Seismic Protection of nonstructural Components, Seismic Design Categorical B worksheet.

C. NONSTRUCTURAL INVENTORY FORM

The intent is that Appendices C, D and E be used together as tools for the facility survey. The first step is to review the map in Figure 3.2.1-1 and discussion in Section 1.3 to see if nonstructural hazard mitigation is a concern for the facility in question. If so, then Appendices C and D can be used in tandem to perform the survey. Risk ratings from Appendix E could be added to the inventory form during the field survey or added later in order to help prioritize the items in the list.

The questions in Appendix D are stated in such a way that the answer "No" or "Unknown" indicates that the component may be noncompliant and likely to pose a nonstructural earthquake hazard. All of the noncompliant components should be entered as individual line items on the facility inventory form in this Appendix. As shown below, the form provides columns for the following information:

- Priority: This can be added at the end after the priorities have been established.
- Nonstructural Item: Name or description of nonstructural component.
- Location: Information such as building, floor, or room number.
- Quantity: Number of items, lineal feet, or square feet.
- Risk Rating for Life Safety (LS), Property Loss (PL) and Functional Loss (FL) from Appendix E.
- Notes: Space for comments regarding the current condition, presence or absence of anchorage details, proximity to other hazardous items, issues with secondary damage such as leaks or hazardous materials release, and whether the component in question is important for functionality of the facility. This might also include a photo number if photos of each item are taken to assist with the survey.

The inventory form provided here has been adapted from the spreadsheet provided by the U.S. Bureau of Reclamation on their website under the heading "Online Orders/Free Tools," <http://www.usbr.gov/ssle/seismicsafety/onlineorders.html>. The website contains two types of downloadable survey forms: one in spreadsheet format (Microsoft Excel) and one in database

format (Microsoft Access). Both of these forms have built-in sorting algorithms so that components with high risk in any category can be shifted to the top of the list. These sorting criteria may be adjusted to suit individual needs. Survey forms can be customized to include cost data, which may be useful for prioritization and planning. Proprietary forms are also available for purchase from specialty vendors.

PRIORITY INVENTORY									Rank by LS	Rank by PL	Rank by Highest Rank	
ID	Description	Location	Quantity	Units	LS	PL	LF	Detail Type	Notes			
					"H", "M", or "L"			NE, PR, ER				
1	Bookcase in the south east corner	Room 13	2 each		H	M	M	NE	The two wooden bookcases are unanchored and could tip over during an earthquake blocking egress. Relocate the bookcases away from the doorway or anchor them to the supporting floor or adjacent wall.			
6	Computer monitor	04-N3	1 each		H	H	L	NE	Equipment stored less than four feet above the floor, like this computer monitor, is not a significant life safety hazard. However consideration should be made to securing these types of equipment to the desk top or adjacent wall.			
82	Bookcase	02-12 South Elevation	3 each		H	M	M	NE	Tall shelving or bookcases that have width to height ratios greater than four should be attached to the supporting floor or adjacent wall.			
182	Unreinforced Masonry parapet	50 LF			H	H	L	ER				
13	File cabinets	04-W4	3 each		M	M	M	NE	These flat files are three individual units stacked on top of each other. Without lateral restraints, they can easily slide off each other.			
16	Hot water heater	04-W7	1 each		M	H	L	PR	Gas hot water heaters should be anchored to the floor or adjacent wall to prevent tipping and damage to water and gas lines.			
65	Vending machine	02-15	1 each		M	M	L	NE				
83	Suspended ceiling	02-12	150 SF		M	M	M	PR	The suspended ceiling tiles are supported vertically to the roof structure. There are no lateral tie wires to compensate for lateral loads due to seismicity.			
85	Natural gas supply line	02 North Elevation	200 each		M	M	M	ER	Each gas line that enters the building should have an automatic shutoff valve to prevent escaping gas from feeding a potential fire.			
138	Credenza	04-N4	1 each		M	M	L	NE	The credenza should be anchored to the desk top or adjacent wall to prevent a potential falling hazard.			
63	Computer cabinet	02-14a	1 each		L	H	M	NE	Computer hub should be anchored to the floor or adjacent wall to limit potential damage.			
86	Communication hub	04-W8	1 each		L	L	L	NE	The communication equipment should be stored inside of protective cabinets to prevent potential damage from falling debris.			
178	Desktop computer with monitor	04-E110	2 each		L	M	L	NE	Computers could be placed on the floor to limit potential damage to stored data or the computer's electrical components. The monitor should also be anchored to the desk.			

Figure C-1 Sample inventory checklist for a facility located in an area with Moderate seismic risk. The sorting algorithm of the spreadsheet makes this a useful tool for prioritization. The electronic file is free to download from the U.S. Department of the Interior Bureau of Reclamation's website, <http://www.usbr.gov/ssle/seismicsafety/onlineorders.html>.

D. CHECKLIST OF NONSTRUCTURAL SEISMIC HAZARDS

This checklist is intended to be used in surveying buildings to assess whether the nonstructural elements (architectural, MEP, FF&E, or contents) pose a danger to the building occupants or are likely to cause financial loss or interruption following an earthquake.

This checklist of nonstructural hazards is intended for use in areas where seismic hazards are a significant concern. Review the discussion in Section 1.3 for the applicability of these nonstructural guidelines and the sidebar in Section 5.3.1 for rules regarding exemptions from the nonstructural provisions in ASCE/SEI 7-10 *Minimal Design Loads for Buildings and Other Structures* (ASCE, 2010) that apply to new construction.

The form includes eight columns marked as follows:

ITEM NO.: ID number to indicate the type of component (architectural, MEP, FF&E or contents) and the subgroup. These numbers are based on the section or subsection in this text and as shown in the tables in Chapter 6.

COMPONENT NAME(S): Name or description of item.

PRINCIPAL CONCERNS: List of problems often associated with this type of item such as falling hazard, water or fuel leakage, broken glass. These concerns should be taken into account when answering the checklist questions. For example, the primary concern for adhered veneer is that it may pose a falling hazard. If a facility has adhered veneer, but only at the base of the building below 6 ft, then this might be checked "Compliance," if the purpose of the survey is to identify life safety hazards or might be rated "Noncompliance," if the survey is also intended to help control property damage and limit losses.

EXAMPLE: Example number. All examples, which contain photos and detailed drawings when applicable, can be found in Chapter 6.

COMPLIANCE (C): The questions in this form have been stated in such a way that an affirmative answer indicates that the item is not likely to pose a nonstructural hazard.

NONCOMPLIANCE (NC): The questions in this checklist are stated in such a way that the answer "No" or "Unknown" indicates that the component may be noncompliant and likely to pose a nonstructural earthquake hazard. All of the noncompliant components should be entered as individual line items on the facility inventory form in Appendix A. Comments should be entered in the survey form noting the location, condition, presence or absence of anchorage details, proximity to other hazardous items, issues with secondary damage such as leaks or hazardous materials release, and whether the component in question is important for functionality of the facility.

NOT APPLICABLE (N/A): This column should be checked if none of the listed items are present and has been included, so that it is clear that the item was not missed or overlooked when performing the survey.

CHECKLIST QUESTIONS: Questions are all "Yes-No" questions, which are answered by checking the appropriate box from among the previous three columns.

6.3 Architectural Components							
Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
6.3.1	Exterior Wall Components						<i>[Exterior falling hazards are a primary concern, especially items situated above 10 feet and items that may fall over exits, walkways, or sidewalks.]</i>
	Adhered veneer	Falling hazard	6.3.1.1				Is the adhered veneer adequately attached to the structure? [This includes relatively thin sections of tile, masonry, stone, terra cotta, ceramic tile, glass mosaic units, stucco, or similar materials attached to a structural wall or framework by means of an adhesive].
							Based on visual observations and/or tapping, is the veneer free of cracked or loose sections that may fall during an earthquake?
	Anchored veneer	Falling hazard	6.3.1.2				Is the anchored veneer adequately attached to the structure? [This includes thicker masonry, stone, or stone slab units that are attached to the structure by mechanical anchors].
							Is the masonry or other veneer supported by shelf angles or other elements at each floor?
							Is the masonry or other veneer connected to a structural back-up wall at adequate spacing?
							Has the veneer been adequately maintained? Are the anchors in good condition, free of significant corrosion, and inspected regularly?
	Prefabricated panels	Falling hazard, damage to panels and connections, broken glass	6.3.1.3				Were the panels and connections designed by an architect or engineer to accommodate the expected seismic distortion of the surrounding structure?
							Are prefabricated cladding panels detailed to allow relative movement between the panel and the structure?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Are prefabricated panels supported for vertical loads with at least two connections per panel?
							Are prefabricated panels supported for out-of-plane loads with at least four connections per panel?
							Have the panels been adequately maintained? Are the panel connections in good condition, free of significant corrosion, and inspected regularly?
							Are there adequate separations between panels so they will not come into contact with each other during an earthquake?
	Glazing exterior wall system	Falling hazard, broken glass	6.3.1.4				Is it known that the glazing was designed by an architect or engineer to accommodate the expected seismic distortion of the surrounding structure?
							Do large window panes and storefront windows have safety glass? [All exterior glazing should be laminated, annealed or laminated heat-strengthened safety glass or other glazing system that will remain in the frame when the glass is cracked. This is particularly important for glazing located over 10 feet above an exterior walking surface].
	Glass blocks	Falling hazard, broken glass	6.3.1.5				Are partial-height glass block walls laterally braced to the structure?
							Is the glass block reinforced with panel anchors and panel reinforcing wire?
	Overhead glazing or skylights	Falling hazard, broken glass	6.3.1.6				Are transoms (glass panes over doors) made of safety glass?
							Are skylights made of safety glass or covered with shatter-resistant film?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Are large panes made of safety glass or is it known whether the glazing assembly was designed by an architect or engineer to accommodate the expected seismic distortion of the surrounding structure?
6.3.2	Partitions						
	Heavy	Falling hazard; collapse or spalling with debris in exitways; large cracks often mistaken for structural damage	6.3.2.1				Are block wall partitions reinforced? [This would include concrete masonry unit (CMU), brick, and hollow clay tile partitions. Most brick and hollow clay tile walls in pre-1933 buildings in California are unreinforced; unreinforced masonry partitions may still be found in current construction in other parts of the country.]
							Are unreinforced masonry walls braced at regular intervals? [In zones of low and moderate seismicity, are partitions braced at 10 foot intervals or less? In zones of high seismicity, are partitions braced at 6 foot intervals or less?]
							Are full-height CMU partitions detailed to allow sliding at the top?
	Light	Cracking of plaster or gypsum board; costly to patch and paint	6.3.2.2				Are partial-height stud wall partitions braced to the structure above the ceiling line?
							Are full-height stud wall partitions detailed to allow sliding at the top?
							If partitions function as lateral support for tall shelving or other nonstructural components, are these partitions adequately anchored or braced to the structure above the ceiling line?
	Glazed	Broken glass	6.3.2.3				Are interior glazed or glass block partitions laterally braced to the structure?
6.3.3	Interior Veneers						

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
	Stone and tile	Falling hazard, debris in exitways	6.3.3.1				Is the adhered veneer adequately attached to the structure?
							Is the anchored veneer adequately attached to the structure?
6.3.4	Ceilings, Soffits						
	Suspended acoustic lay-in tile ceiling	Dropped acoustical tiles, perimeter damage, separation of runners and cross runners; falling hazard if grid and lights come down	6.3.4.1				Does the suspended ceiling have adequate diagonal bracing wires and compression struts to support seismic loads from the ceiling grid plus all lay-in items that do not have independent lateral supports?
							If the ceiling supports lay-in lighting or diffusers, do the lay-in items all have independent vertical supports consisting of wires located at least at two diagonally opposite corners?
							Do lay-in fixtures weighing over 50 pounds additionally have independent lateral bracing wires at all four corners?
							If located in a high seismic zone, is the suspended ceiling supported by a heavy duty ceiling grid with adequate capacity and does the grid include supplemental hanger wires at light fixtures or other mechanical items?
	Directly applied to structure	Falling hazard	6.3.4.2				Are decorative ceiling panels and/or latticework securely attached, particularly beneath exterior eves over exits?
							Are decorative finishes and/or latticework on beam soffits or beneath exterior eaves securely attached, particularly over exits?
							For plaster ceilings or stucco soffits, is the wire mesh or wood lath securely attached to the structural framing above?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Is the plaster or stucco in good condition and not deteriorated by water damage or corrosion?
	Suspended heavy ceilings	Falling hazard	6.3.4.3				If the suspended gypsum board ceiling extends over more than one level, does the suspended ceiling system have adequate diagonal bracing?
							Is the suspended wire mesh or wood lath securely attached to the structural framing above?
							Is the plaster ceiling in good condition and not deteriorated by water damage?
6.3.5	Parapets, Appendages, Roof Tiles						
	Unreinforced masonry parapet	Falling hazard	6.3.5.1				Are unreinforced masonry parapets adequately braced? [If there is a local parapet ordinance, is it known if the bracing complies with the local ordinance?]
	Parapets, cornices, appendages	Falling hazard					Are parapets and cornices reinforced and adequately braced?
							Do other decorative elements and appendages have positive anchorage to the building?
							Are hanging appendages braced or secured with a safety cable?
6.3.6	Canopies, Marquees, Signs						
	Canopy, Marquees, Signs	Falling hazard	6.3.6.1				Are cantilevered elements braced to the structure with steel shapes, not chains, to provide restraint and prevent bouncing?
							Are exterior signs or billboards adequately braced and anchored?
							Are interior signs securely attached with positive connections?
	Flagpoles	Falling hazard					Are flagpoles securely attached to the structure?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
6.3.7	Chimneys and Stacks						
	Unreinforced masonry chimney	Falling hazard	6.3.7.1				Is the brick chimney restrained with braces to the roof near the top of the chimney?
							Is the brick chimney anchored near the roof line?
	Stacks	Falling hazard					Are stacks anchored to the supports or foundation by means of anchor bolts of adequate length and double nuts?
6.3.8	Stairways						
	Stairways		6.3.8.1				Do steel stairs in multistory buildings have sliding supports at one end that can accommodate the anticipated interstory displacements?
							Have any unreinforced masonry partitions, piping, or lighting in stairwells been removed, strengthened, encapsulated or braced, especially if the stairway is used as a primary exit route?
6.3.9	Freestanding Walls or Fences						
	Freestanding Walls or Fences	Falling hazard if over 4' tall	6.3.9.1				Were freestanding walls or fences designed by an architect/engineer to resist lateral forces?
							Are CMU walls adequately reinforced with vertical bars set in grout-filled cells and horizontal bars embedded in the mortar joints?
							Were CMU walls or fences built with adequate foundations to prevent them from tipping over in an earthquake?

6.4 Mechanical, Electrical and Plumbing Components							
Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
6.4.1	Mechanical Equipment						
	Boilers, furnaces, pumps and chillers (HVAC wet-side equipment)	Sliding, overturning, broken gas/fuel or exhaust lines, leaking fluids, loss of function	6.4.1.1				Are the boilers, pumps, chillers and similar wet-side HVAC equipment securely anchored to the floor or wall with adequately sized bolts?
							Do HVAC wet-side equipment items that are mounted on vibration isolators have adequate lateral restraint provided by snubbers, bumpers, or restrained vibration isolators?
							Are housekeeping pads under boilers and similar equipment anchored to the floor slab?
							Does the gas line have a flexible connection to the water heater or boiler that is able to accommodate movement?
							Are furnaces, and furnace or boiler bases, constructed without using unreinforced masonry?
	General manufacturing and process machinery	Falling hazards, hazardous material leaks or spills, loss of function	6.4.1.2				Is manufacturing and process machinery and related equipment, cranes, tanks, piping, chutes, and conveyors all adequately restrained and anchored, particularly items that may fall and injure workers, result in hazardous materials release, or create hazardous electrical conditions?
							Have all life safety hazards been addressed by bracing or anchoring clear falling hazards and other hazardous items?
							If immediate occupancy or operations is a project objective, has a design professional familiar with nonstructural anchorage of manufacturing and process machinery been engaged to perform a detailed survey of the plant?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
	HVAC equipment with vibration isolation	Fall off isolators, overturning, broken gas/fuel or exhaust lines, leaking fluids, loss of function	6.4.1.3				Do HVAC dry-side equipment items such as air compressors, fans, blowers and filters that are mounted on vibration isolators have adequate lateral restraint provided by snubbers, bumpers, or restrained vibration isolators?
							If large equipment is mounted on a concrete housekeeping pad, is the pad adequately anchored into the structural slab?
							Do roof-mounted HVAC units that are mounted on vibration isolators have adequate lateral restraint provided by snubbers, bumpers, or restrained vibration isolators?
							For roof-mounted units, are the curbs supporting the vibration isolators securely attached to the structural roof framing?
	HVAC equipment without vibration isolation	Sliding, overturning, broken gas/fuel or exhaust lines, leaking fluids, loss of function	6.4.1.4				Is equipment (e.g. gas-fired boiler, commercial water heater, chiller, etc.) securely mounted to the floor, wall, or roof with adequately sized bolts?
							If large equipment is mounted on a concrete housekeeping pad, is the pad adequately anchored into the structural slab?
							Does the gas or fuel line have a flexible connection that is able to accommodate movement?
							For roof-mounted units, are the curbs supporting the vibration isolators securely attached to the structural roof framing?
							Are wall- or window-mounted window air conditioning units securely mounted to the wall or shelf?
	HVAC equipment	Falling or swinging	6.4.1.5				Is suspended equipment braced or anchored independently from the ductwork?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
	suspended in-line with ductwork	hazard, separate from ductwork, loss of function					Does the equipment have flexible connections to gas, fuel, or electrical lines?
	Suspended equipment	Gas leak, falling hazard	6.4.1.6				Are the suspended room heaters, especially gas-fired ones, laterally supported?
							Are gas-fired heaters fitted with flexible gas connections?
6.4.2	Storage Tanks and Water Heaters						
	Structurally supported tanks and vessels	Tank or vessel rupture, pipe break	6.4.2.1				Is the tank securely attached to the supports?
							Are the tank supports braced in both directions?
							Are the tank supports attached with anchor bolts to concrete walls or foundation pad?
							Is the foundation large enough to keep the tank from sliding or tipping over?
							Is the wall strong enough to support the tank?
	Flat bottom tanks and vessels	Tank or vessel rupture, pipe break	6.4.2.2				Is the tank securely anchored to a concrete slab or foundation?
							Is the foundation large enough to keep the tank from sliding or tipping over?
	Compressed gas cylinders	Gas leak	6.4.2.3				Are all gas cylinders tightly secured with a chain near the top and bottom or otherwise restrained from movement in each direction?
							Are the chains or restraints securely anchored to a wall or counter with screws or bolts rather than clamps?
							If the gas cylinders are attached to piping, are the restraints adequate to prevent damage at the piping connections?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
6.4.3	Water heaters	Gas leak, water leak, loss of function	6.4.2.4				Are the water heaters securely anchored to the floor or wall?
							Do the gas lines or electrical conduit and water lines have flexible connections to the water heater that are able to accommodate movement?
							Does the water heater meet the limitations for use of prescriptive restraints? Is the capacity less than 100 gallons and is there a structural wall within 12 inches?
							Does the wall have adequate strength to restrain the water heater?
6.4.3	Pressure Piping						
	Suspended pressure piping	Breaks, leaks, loss of function	6.4.3.1				Are the pipes laterally restrained at reasonable intervals in each direction?
							Are the restraints securely attached to the structure?
							Are the pipes free of asbestos insulation that could be damaged by movement in an earthquake?
							Are the pipes free of asbestos that would need to be abated before any retrofit work?
	In-line valves and pumps	Loss of function, leaks	6.4.3.2				Are the distribution pumps anchored, or are they mounted on vibration isolation springs with additional seismic lateral restraints?
							Are suspended valves and pumps adequately braced and anchored to structural elements?
	Flexible connections, expansion joints, seismic separations	Breaks, leaks, loss of function	6.4.3.3				Are flexible connections provided where piping connects to rigidly mounted equipment?
							Are flexible connections provided where pipes cross expansion joints or seismic separations between buildings?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Are pipe penetrations through structural walls or framing members large enough to allow for some seismic movement?
	Pipe Risers	Breaks, leaks, loss of function	6.4.3.4				Are risers (vertical runs of piping) laterally restrained at each floor level or roughly at 20 foot intervals?
							For risers subject to thermal expansion and contraction, have the seismic supports been designed to allow ample thermal movement?
	Floor-mounted pipe supports	Breaks, leaks, loss of function	6.4.3.5				Are the pipes laterally restrained at reasonable intervals in each direction?
							Are the restraints securely attached to the structure?
	Roof-mounted pipe supports	Breaks, leaks, loss of function	6.4.3.6				Are the pipes laterally restrained at reasonable intervals in each direction and do the restraints appear adequate for the roof level? [Accelerations at the roof level are typically higher than at lower levels of a building.]
							Are the curbs and restraints securely attached to the structure and protected from weathering and corrosion?
	Wall-mounted pipe supports	Breaks, leaks, loss of function	6.4.3.7				Are the pipes laterally restrained at reasonable intervals in each direction?
							Are the restraints securely attached to the structure?
	Pipe penetrations	Breaks, leaks, loss of function	6.4.3.8				Are pipe penetrations through structural walls or framing members large enough to allow for some seismic movement or are the pipes restrained to prevent impact with the structural element?
6.4.4	Fire Protection Piping						
	Suspended fire protection	Damage to sprinkler	6.4.4.1				Are the fire sprinkler piping components laterally restrained in each direction?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
	piping	heads, leaks, loss of function					Is the ceiling restrained so the ceilings won't break the sprinkler heads?
6.4.5	Fluid Piping, not Fire Protection						
	Hazardous materials	Breaks, leaks, hazardous materials release	6.4.5.1				Is the hazardous material piping laterally restrained at reasonable intervals in each direction?
							Are the restraints securely attached to the structure?
							Where required, does the hazardous material piping have double walls, secondary containment, leak detection systems or monitoring and are these systems designed for seismic loading?
							Do the pipes have flexible connections that are able to accommodate relative movement at locations where they are attached to rigidly mounted equipment or where they cross seismic separations?
							Does piping containing fuel or other hazardous materials have a seismic shut-off valve or excess flow valve?
							If the shut-off for the line is manual, is a wrench stored within easy reach?
	Nonhazardous materials	Breaks, leaks, loss of function	6.4.5.2				Is the piping laterally restrained at reasonable intervals in each direction?
							Are the restraints securely attached to the structure?
							Do the pipes have flexible connections that are able to accommodate relative movement at locations where they are attached to rigidly mounted equipment or where they cross seismic separations?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
6.4.6	Ductwork						
	Suspended ductwork	Collapse, separation, leaking, fumes	6.4.6.1				Are the rectangular distribution ducts larger than 6 sq ft in cross sectional area laterally supported in each direction?
							Are circular ducts larger than 28 inches diameter laterally supported in each direction?
							Are the supports and hangers securely attached to the structure?
							Are the distribution ducts able to accommodate movement at locations where they cross separations between buildings?
	Air diffusers	Drop out of ceiling grid	6.4.6.2				Are the air distribution grills or diffusers anchored to adequately supported sheet-metal ducts or to the ceiling grid or wall?
							Do the diffusers have positive restraint, independent of the ceiling grid, such as at least two vertical hanger wires per diffuser?
6.4.7	Electrical and Communications Equipment						<i>Caution: Only qualified personnel should open access panels on electrical equipment.</i>
	Control panels, motor control centers, switchgear, etc.	Sliding or overturning, broken or damaged conduit or electrical bus	6.4.7.1				Are the control panels, motor control centers, switchgear and similar items all properly anchored to the floor or laterally supported by a structural wall?
							Do the walls used to support these electrical cabinets have adequate strength to restrain these items?
	Emergency generator	Failed vibration isolation mounts; broken fuel, signal, power	6.4.7.2				Is the emergency generator adequately secured, especially if mounted on motor vibration isolation springs?
							Is the concrete housekeeping pad adequately anchored to the structural slab?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
		and exhaust lines; loss of function					Is the diesel fuel tank adequately braced and anchored? (Refer to additional questions for structurally supported tanks and vessels).
							Are the fuel lines, cooling water lines, and exhaust flues for the emergency generator attached with flexible connections that are able to accommodate relative movement at junctions to spring-mounted equipment, at building entry and exit points, and at expansion joints within the building?
							Have all the components of the emergency power generating system and the electrical distribution system been checked as part of this survey?
	Transformers	Sliding, oil leakage, bushing failure, loss of function	6.4.7.3				Are transformers properly anchored to the floor or wall?
	Batteries and battery rack	Batteries fall, rack tips; loss of emergency power	6.4.7.4				Are the batteries securely attached to the battery rack?
							Is the battery rack cross-braced in both directions?
							Does the battery rack have anchor bolts secured to a concrete foundation pad?
							Is the foundation large enough to keep the battery rack from sliding or tipping?
	Photovoltaic power systems	Falling hazard for roof mounted panels	6.4.7.5				Are the solar panels securely anchored to the roof?
							Is the piping laterally restrained?
	Communications equipment	Sliding, overturning, or toppling	6.4.7.6				Is the microwave communications equipment (antennae, receiver, transmitter, etc.) securely supported and/or anchored?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
		leading to loss of function					Are the components of the public address system and phone system secured?
6.4.8	Electrical and Communications Distribution Equipment						
	Electrical raceways, conduit, cable trays	Electrical hazards, loss of function	6.4.8.1				Are the raceways, bus ducts, and cable trays all laterally braced, including both transverse and longitudinal braces at reasonable spacing?
							Are electrical cables or conduit able to distort at the connections with the equipment or where they cross seismic joints between buildings?
	Distribution panels	Electrical hazards, loss of function	6.4.8.2				Are the electrical distribution panels securely anchored to the floor or wall?
6.4.9	Light Fixtures						
	Recessed	Falling hazards	6.4.9.1				Are recessed lights securely attached to the ceiling grid to resist seismic shaking and is the ceiling grid adequately braced?
							Do the lay-in fluorescent light fixtures have positive support, independent of the ceiling grid, such as at least two diagonally opposite hanger wires per light fixture?
							Do lay-in fixtures weighing more than 50 pounds have independent lateral support?
							Are lens covers attached or supplied with safety devices?
	Surface-mounted	Falling hazards	6.4.9.2				Are spot lights or track lights securely attached to resist seismic shaking?
							Are exterior light fixtures properly supported or securely attached to the structure?
							Are emergency lights and exit lights mounted to protect them from falling off the wall or off shelf supports?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
	Pendant light fixtures	Falling hazard, light fixture or unrestrained bulbs	6.4.9.3				Do chandeliers or other hanging fixtures have safety cables to prevent them from impacting each other or a window?
							Are lens covers attached or supplied with safety devices?
							Do pendant or stem light fixtures have safety cables so they will not fall if the fixture sways and breaks the stem connection, or are they braced to prevent swaying?
	Heavy light-fixtures	Falling hazards	6.4.9.4				Are heavy light fixtures, such as operating room lights, adequately braced and anchored to the structure independent of the ceiling system?
6.4.10	Elevators and escalators						<i>Caution: The moving parts or components of these systems need to be evaluated by qualified personnel. Inappropriate seismic restraints may compromise the safe operation of these systems.</i>
	Hydraulic elevator	Loss of function	6.4.10.1				Are the components of the hydraulic system properly anchored?
	Traction elevator	Loss of function, counter-weights out of guide rails, cables out of sheaves, dislodged equipment	6.4.10.2				Are the cables installed in such a way that they are protected against misalignment during an earthquake?
							Is the elevator cab properly attached to the guide rails?
							Are the counterweights properly attached to the guide rails?
							Are the guide rails securely attached to the building?
							Are the motor and motor control cabinets properly anchored?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
6.4.11	Escalators	Loss of function	6.4.10.3				Is the elevator equipped with a seismic switch?
							Is the escalator control equipment securely anchored?
							Is it known if the escalator was designed by an engineer to accommodate relative movement between floors during an earthquake?
							Is the control equipment for the moving walkway properly anchored?
6.4.11	Conveyors, material handling						
	Conveyors	Loss of function, falling hazard if elevated, contents fall	6.4.11.1				Are supports for the conveyors properly anchored to the floor or wall?
							Is the conveyor control equipment properly anchored?

Section	Furniture, Fixtures & Equipment and Contents						
Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
6.5.1	Storage racks						
	Light duty shelving	Contents fall, shelves damaged	6.5.1.1				Are tall shelving units securely anchored to the floor or walls?
							If walls are used for lateral support, has the capacity of the walls been checked for adequacy to restrain the shelving?
							Are heavily loaded shelving units supported in both directions?
							For shelving units significantly taller than wide, are large anchor bolts used to anchor each leg to a concrete slab?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Are breakable items secured to the shelves, or are they stored in stable units (e.g., are they shelved in the original packing boxes, or are small items shrink-wrapped together)?
	Industrial storage racks	Contents fall, racks damaged	6.5.1.2				Are industrial storage racks braced and anchored to a concrete floor slab or concrete walls?
							If walls are used for lateral support, has the capacity of the walls been checked for adequacy to restrain the shelving?
							Has the capacity of the concrete floor slab been checked for adequacy to resist uplift of the storage racks?
							Are the racks equipped with dampers, base isolation, or other specialized seismic restraint systems?
6.5.2	Bookcases, Shelving						
	Bookshelves	Contents fall, shelving damaged	6.5.2.1				Are bookshelves 5' or taller properly anchored with brackets to a solid wall or studs, or anchored to the floor, particularly if they are located next to a bed or desk or where they could block an exit?
							Does the wall or partition used to anchor the book shelves have adequate strength to support seismic loading from the shelving?
							Are bookshelves fitted with edge restraints or elastic cords to keep books from falling?
							Are large and heavy books located on the lowest shelves?
	Library and other shelving	Contents fall, shelving damaged	6.5.2.2				Is it known if the lateral supports for the library stacks and shelving have been designed by an architect or engineer?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Are library shelving and stacks properly braced and anchored to the floor and walls, including bracing to the floor above if shelving is tall and slender that tie the shelving units together?
							If all shelving units are not independently braced or anchored, are adjacent units fastened together with bolts or other mechanical fasteners?
							Do walls or partitions used to anchor library stacks have adequate strength for the imposed lateral loads?
							Are bookshelves fitted with edge restraints or elastic cords to keep books from falling?
							Are large and heavy books located on the lowest shelves?
							Are rare or fragile books given extra protection to prevent falling and water damage?
6.5.3	Computer and Communications Equipment						
	Computer access floors and equipment	Collapse, separation between modules, loss of function	6.5.3.1				Are the support pedestals for computer access floors anchored to the floor and braced with diagonal steel members, or is it verified that the vertical pedestals are a seismically qualified model, installed in accordance with the manufacturer's recommendations?
							Do cable openings in the access floor have edge guards to prevent equipment legs from sliding into the openings
							Are computers, tape racks, and associated equipment that are about twice as tall as wide, anchored, tethered, and/or laterally supported?
							Does heavy computer equipment have supports which are braced and anchored to the structural floor slab independently of the computer access floors?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Is computer cabling long enough to accommodate lateral movement within the building?
	Computer and communication racks	Lost data or damaged equipment may cause downtime	6.5.3.2				Is computer information vital to operations backed up and stored off-site?
							Is critical computer and communications equipment securely anchored to the rack?
							Are computer and communication racks securely anchored to the floor or wall?
							Is sensitive computer or communications equipment located out of range of fire sprinkler heads or joints in the sprinkler pipes where they are less prone to water damage if the sprinkler lines break?
	Desktop computers and accessories	Falling hazard, lost data or damaged equipment may cause downtime	6.5.3.3				Are computers and monitors anchored to desktops?
							Are desktop or countertop computers and printers mounted with positive restraint, resting on high-friction rubber pads, or located far enough from the edges of desks and tables to prevent them from sliding and falling in an earthquake?
	Televisions and video monitors, wall-mounted	Falling hazard	6.5.3.4				Are wall- or overhead-mounted television sets, video monitors, surveillance cameras or sound system speakers securely braced and anchored to the wall or ceiling or equipped with safety cables?
6.5.4	Hazardous materials storage						
	Hazardous materials storage	Hazardous material release, mixing of incompatible substances	6.5.4.1				Are chemical supplies secured with shelf lips several inches high, or are they stored in "egg crate" containers in drawers, so that the containers will not overturn or fall and spill?
							Are chemicals stored in accordance with manufacturers' recommendations?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Are incompatible chemicals stored at an appropriate distance from one another so that they will not mix if the containers are broken?
							Are the chemicals in each cabinet catalogued properly and marked clearly?
							Are Material Safety Data Sheets (MSDSs) stored in a location separate from the chemicals?
							Are cabinets for hazardous materials securely attached to the floor or to a sturdy wall?
							Has asbestos insulation been removed, or has it been encapsulated to reduce the possibility of damage in an earthquake?
							Is the facility free of asbestos that would need to be abated before any retrofit work?
6.5.5	Miscellaneous FF&E						
	File cabinets	Cabinets fall, may block exits, contents spill	6.5.5.1				Do the file cabinet drawers or doors latch securely?
							Are tall file cabinets anchored with wall brackets to a solid wall or studs, anchored to the floor, or bolted to one or more adjacent cabinets to form a more stable configuration, i.e., a larger "footprint"?
							Are unanchored cabinets located so that they will not fall or slide and block a door or exit?
	Demountable partitions	Collapse, block exit path	6.5.5.2				Are demountable partitions attached to each other and arranged in a stable layout with many perpendicular wall segments?
							Are partial-height partitions anchored to the floor?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							If tall shelving or cabinets are located next to the partitions, can these items be moved or independently anchored to the floor or structure?
	Miscellaneous furniture and fixtures	Falling hazard	6.5.5.3				Are tall items located near beds or desks securely anchored to a wall with adequate capacity?
							Are large kitchen and laundry equipment all securely anchored to the floor, wall, or countertop with adequate capacity?
							Are vending machines tethered a column or wall to prevent tipping and sliding?
							Are unanchored furnishings located where they cannot slide or overturn to block corridors or doors?
							Are heavy wall pictures and other wall hangings well anchored to the studs or structural framing?
							Are heavy hanging plants secured to prevent falling or impact with windows?
6.5.6	Miscellaneous Contents						
	Shelf-mounted items	Contents fall, items broken or mixed	6.5.6.1				Are valuable or fragile items protected against tipping or falling off shelving?
							Are the drawers and cabinet doors latched securely, e.g., with special latches or baby-proof hardware that will not fly open in an earthquake?
							Are rare or valuable items (rare books, museum collections, medical records) given extra protection against falling and water damage?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Are heavy potted plants on file cabinets or tall shelves restrained to prevent falling?
	Desktop, countertop items		6.5.6.2				Is radio equipment restrained to keep it from sliding off shelving or tabletops?
							Is important equipment restrained to keep it from sliding off shelving or tabletops?
							Are fax machines restrained or placed far enough from the edge that they will not slide and fall off?
							Is the public address system restrained to prevent the equipment from sliding and falling off the shelving?
	Fragile artwork	Loss of rare or expensive art objects, falling hazards	6.5.6.3				Are heavy sculptures anchored to prevent overturning during an earthquake?
							Are heavy wall-mounted paintings, mirrors, or other wall hangings well anchored to structural studs or framing?
							Do hanging sculptures or mobiles have a safety cable to prevent them from swinging excessively, impacting windows or other artwork, or falling?
							Are fragile items restrained by mono-filament lines, hook and loop material, Plexiglas display cases, or some other seismic safety device?
	Fire extinguisher and cabinet		6.5.6.4				Are the fire extinguisher cabinets and/or hose cabinets securely mounted?

Emergency Systems							
Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
	Emergency Egress						<i>Emergency system components were not covered in the body of the document but are an important consideration for providing earthquake safety.</i>
	Emergency Egress	Exit doors jammed, corridors blocked, no emergency lighting, falling hazards	6.6.1.1				If primary exit doors are heavy metal fire doors that might jam if the building racks during an earthquake, is there a crowbar or sledgehammer located near the exit to facilitate emergency exiting?
							Do automatic doors with optical or floor sensors and mechanized roll-up doors have a manual override in case of a power outage after an earthquake?
							Are the building utilities and architectural finishes along egress routes (piping, ducts, ceilings, lights, partitions, etc.) braced or anchored adequately to prevent falling obstructions and to keep the egress routes clear after an earthquake?
							Are the furniture and contents along egress routes (desks, supply cabinets, shelving, etc.) braced or anchored adequately to prevent falling obstructions and keep the egress routes clear after an earthquake?
							Are unanchored furniture and contents along egress routes kept far enough from the exits so they will not fall or slide and obstruct the doors?
							Have any unreinforced masonry walls in stairwells, corridors, and elevator enclosures been removed, strengthened, or encapsulated to prevent collapse during an earthquake?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
							Are parapets, canopies, veneers, cornices and any other ornamentation above building exits braced and anchored to prevent collapse?
							Are emergency lights and exit lights securely mounted to protect them from falling off walls or shelf supports during an earthquake?
							Are transoms, skylights, corridor glazing or glazing above exits made of safety glass or covered with shatter-resistant film?
							If the building has elevators, does the elevator have a seismic switch?
	Emergency Power Generation and Distribution System	Loss of function					Is the emergency generator adequately secured, especially if mounted on motor vibration isolation springs?
							Is the concrete housekeeping pad adequately anchored to the structural slab?
							Is the diesel fuel tank adequately braced and anchored?
							Are the batteries and battery racks adequately braced and anchored?
							Are the fuel lines, cooling water lines, and exhaust flues for the emergency generator attached with flexible connections that are able to accommodate relative movement at junctions to spring-mounted equipment, at building entry and exit points, and at expansion joints within the building?
							Have the transformer, MCC, switchgear and bus ducts been checked?
							Have all the components of the emergency power generating system and the electrical distribution system been checked as part of this survey?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)
Fire Detection and Protection System	Loss of function						Are fire and smoke detectors properly mounted?
							Is the control equipment for the fire alarm system and automatic fire doors securely anchored?
							Are the fire extinguisher cabinets and/or hose cabinets securely mounted?
							Are the fire extinguishers secured with quick-release straps?
							Are the fire sprinkler piping components laterally restrained in each direction?
							Is the ceiling restrained so the ceilings won't break the sprinkler heads?
							Are the distribution lines able to accommodate movement where they cross between buildings?
							Is the fire water pump anchored, or is it mounted on vibration isolation springs with additional seismic restraints?
							Is the emergency water tank or reservoir securely attached to its supports?
							Are the tank supports anchored to the floor and braced in both directions?
							Are the supports or braces properly anchored to the foundation?
							Are the smoke control fans properly supported and/or anchored?
							Are the fan control centers securely anchored?
	Emergency Supply Cabinet	Supplies inaccessible in emergency					Is the cabinet properly braced and anchored to the floor and/or walls?

Item No.	Component Name	Principal Concerns	Example	C	NC	NA	Checklist Questions (Yes=Compliance; No or Unknown=Noncompliance; NA=Not Applicable)

E. NONSTRUCTURAL SEISMIC RISK RATINGS

The risk ratings that appear in this Appendix are provided as an aid to establishing priorities and are based on the following definitions and assumptions:

SHAKING INTENSITY: For a particular geographic location in the United States, the shaking intensity may be estimated by using the seismic map in Figure 3.2.1-1 that shows the areas that are likely to experience minimal, low, moderate, or high ground shaking during future probable maximum considered earthquake events that may affect the areas. The shaking intensity estimates based on the map in Figure 3.2.1-1 should be adequate for items situated at or near the ground in simple, nonessential facilities. For other situations, it may be advisable to choose the next higher shaking intensity or to seek the advice of professional consultants. Note that for areas with light shaking, a full blown upgrade of nonstructural components may not be warranted, unless an owner is particularly risk averse; the current code would not require many of the protective measures recommended herein, even for new construction.

LIFE SAFETY (LS) RISK: Risk of being injured by the item. This does not include the overall impact on life safety systems in a building, such as loss of emergency power in a hospital or loss of fire detection capability. These disruptions of service are covered under Function below.

PROPERTY LOSS (PL) RISK: Risk of incurring a repair or replacement cost because of damage to the item. This property loss, as used here, includes the cost of fixing a broken pipe but not the indirect cost of water leakage damage, and includes the cost of repairing a computer but not the loss of business revenue computer downtime might cause. These indirect effects cannot be estimated here on a generic basis.

FUNCTIONAL LOSS (FL) RISK: Risk that the item will not function because it has been damaged. This includes some consideration of the impact of this loss of function of the component on the operation of an ordinary occupancy building. Not included are off-site functional impacts, such as the loss of function of a piece of equipment because of a city-wide power outage. Outages of power, water, and other utility company or agency services are real problems to consider but are outside the scope of the item-by-item ratings here.

TYPE OF DETAIL: For components where an illustrated example is provided in Chapter 6, the detail type is indicated as Non-engineered (NE), Prescriptive (PR), or Engineering Required (ER). The example number (e.g. 6.3.1.1 for adhered veneer) is shown at the left.

ASSUMPTION 1: The risk ratings are based on the assumption that the item has been installed without seismic bracing, seismic anchorage, seismic restraint, or allowance for differential movements. In areas of the U.S. where seismic building code provisions have only recently been enforced, this assumption will be generally true. In areas of the western U.S. where seismic codes have been enforced for some time, this assumption may not always be true. Particularly in buildings constructed in the western states since the mid-1970s, some nonstructural items may be anchored or braced, but the assumption of unanchored and unbraced items will still be true for many items on these lists.

ASSUMPTION 2: The item is assumed to be located at or near the ground level, or in a low-rise building. The most common case of a relatively stiff low-rise building with structural walls is presumed in the ratings here. Items such as full-height partitions and glazing are more likely to be damaged in flexible buildings that experience large lateral deformations. Damage to items sensitive to imposed deformation will be greater in buildings or portions of buildings that are more flexible, such as mid- and high-rise buildings; flexible frame buildings without significant structural walls; "soft stories" of buildings with structural walls in most stories but with a story, typically the ground story, that is much less laterally stiff because of the absence of walls; and the "soft wall" sides of bearing wall buildings where there is little or no solid wall area, such as the face of a typical commercial storefront building.

ASSUMPTION 3: For building occupancy, an ordinary occupancy category is assumed. Thus, in the case of essential or specialized facilities, some nonstructural components would be rated differently. For example, in this appendix the risk ratings are given for shelving in an ordinary occupancy building, but the same shelving would be rated quite differently with regard to Life Safety risk in a lab, Property Loss risk in a museum, or risk of Functional Loss in a communications center.

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
6.3	Architectural Components					
6.3.1	Exterior Wall Components					
6.3.1.1	Adhered veneer	Low	M	M	L	ER
		Mod	H	H	L	
		High	H	H	L	
6.3.1.2	Anchored veneer	Low	M	M	L	ER
		Mod	H	H	L	
		High	H	H	L	
6.3.1.3	Prefabricated panels	Low	M	M	L	ER
		Mod	H	H	L	
		High	H	H	L	
6.3.1.4	Glazed exterior wall system	Low	L	L	L	ER
		Mod	M	M	L	
		High	H	M	M	
6.3.1.5	Glass blocks	Low	L	L	L	ER
		Mod	M	M	L	
		High	H	M	M	
N/A	Overhead glazing or skylights	Low	L	L	L	
		Mod	H	M	L	
		High	H	M	M	
6.3.2	Partitions					
6.3.2.1	Heavy (CMU, brick, hollow clay tile)	Low	L	L	L	ER
		Mod	H	H	H	
		High	H	H	H	
6.3.2.2	Light (partial- or full-height stud wall partitions)	Low	L	L	L	ER
		Mod	M	M	H	
		High	M	H	H	
6.3.2.3	Glazed	Low	L	L	L	ER
		Mod	M	M	L	
		High	H	H	M	
6.3.3	Interior Veneers					
6.3.3.1	Stone and tile	Low	L	L	L	ER
		Mod	H	H	M	
		High	H	H	M	
6.3.4	Ceilings					
6.3.4.1	Suspended acoustic lay-in tile ceiling	Low	L	L	L	PR
		Mod	M	M	M	
		High	H	H	H	

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
6.3.4.2	Directly applied to structure	Low	L	L	L	NE
		Mod	M	M	M	
		High	H	H	H	
N/A	Soffits (stucco, gypsum board, plaster)	Low	L	L	L	
		Mod	M	M	M	
		High	H	H	H	
6.3.4.3	Suspended heavy ceilings	Low	L	L	L	PR
		Mod	M	M	M	
		High	H	H	H	
6.3.5	Parapets, Appendages, Roof Tiles					
6.3.5.1	Unreinforced masonry parapet	Low	M	M	L	ER
		Mod	H	H	L	
		High	H	H	L	
N/A	Parapets, cornices, decoration	Low	M	M	L	
		Mod	H	H	L	
		High	H	H	L	
N/A	Hanging appendages	Low	L	L	L	
		Mod	H	H	L	
		High	H	H	M	
N/A	Clay roof tiles	Low	L	L	L	
		Mod	L	M	L	
		High	M	H	M	
6.3.6	Canopies, Marquees, Signs					
6.3.6.1	Canopies, Marquees, Signs	Low	L	L	L	ER
		Mod	H	H	L	
		High	H	H	M	
N/A	Heavy signs or exterior billboards	Low	L	L	L	
		Mod	H	H	L	
		High	H	H	L	
N/A	Flagpoles	Low	L	L	L	
		Mod	L	L	L	
		High	M	M	L	
6.3.7	Chimneys and Stacks					
6.3.7.1	Unreinforced masonry chimney	Low	L	L	L	ER
		Mod	M	M	L	
		High	H	M	M	
N/A	Stacks, small	Low	L	L	L	

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
		Mod	M	M	L	
		High	H	M	M	
6.3.8	Stairways					
6.3.8.1	Stairways	Low	L	L	L	ER
		Mod	H	M	L	
		High	H	M	H	
6.3.9	Freestanding Walls or Fences					
6.3.9.1	Freestanding Walls or Fences	Low	L	L	L	PR
		Mod	L	L	L	
		High	H	H	M	
6.4	Mechanical, Electrical, & Plumbing Components					
6.4.1	Mechanical Equipment					
6.4.1.1	Boilers, furnaces, pumps and chillers (HVAC wet side)	Low	L	L	L	ER
		Mod	L	L	L	
		High	M	M	M	
N/A	Boilers and furnaces (rigid mount)	Low	L	L	L	
		Mod	L	L	L	
		High	M	M	M	
N/A	Chillers	Low	L	L	L	
		Mod	L	L	L	
		High	L	M	M	
N/A	Heat pumps or heat exchangers	Low	L	L	L	
		Mod	L	L	L	
		High	L	M	M	
6.4.1.2	General manufacturing and process machinery	Low	L	L	L	ER
		Mod	M	M	M	
		High	H	H	H	
6.4.1.3	HVAC equipment with vibration isolation	Low	L	L	L	ER
		Mod	L	M	L	
		High	L	M	M	
N/A	Fans, blowers, filters	Low	L	L	L	
		Mod	L	M	L	
		High	L	M	M	
N/A	Air compressors	Low	L	L	L	

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
		Mod	L	M	L	
		High	L	M	M	
N/A	Roof mounted HVAC units	Low	L	M	L	
		Mod	L	M	L	
		High	M	H	M	
N/A	Roof mounted equipment, vents or flues	Low	L	L	L	
		Mod	L	M	L	
		High	M	M	M	
6.4.1.4	HVAC equipment without vibration isolation (rigid mount)	Low	L	L	L	ER
		Mod	L	L	L	
		High	L	M	M	
N/A	Wall-mounted room air conditioning units	Low	L	L	L	
		Mod	H	M	L	
		High	H	M	L	
6.4.1.5	HVAC equipment suspended in-line with ductwork	Low	L	L	L	ER
		Mod	L	M	L	
		High	L	M	M	
6.4.1.6	Suspended equipment	Low	L	L	L	ER
		Mod	H	H	L	
		High	H	H	L	
6.4.2	Storage Tanks and Water Heaters					
6.4.2.1	Structurally supported tanks and vessels	Low	L	L	L	ER
		Mod	M	H	M	
		High	M	H	M	
N/A	Diesel fuel tank	Low	L	L	L	
		Mod	H	H	L	
		High	H	H	M	
N/A	Propane tank	Low	L	L	L	
		Mod	H	H	M	
		High	H	H	M	
6.4.2.2	Flat bottom tanks and vessels	Low	L	L	L	ER
		Mod	M	H	M	

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
		High	M	H	M	
6.4.2.3	Compressed gas cylinders (oxygen, CO ₂ , ammonia, etc.)	Low	L	L	L	NE
		Mod	M	M	L	
		High	H	M	M	
6.4.2.4	Water heaters	Low	L	L	L	PR
		Mod	M	H	L	
		High	M	H	L	
6.4.3	Pressure Piping					
6.4.3.1	Suspended pressure piping	Low	L	L	L	ER
		Mod	M	M	M	
		High	M	M	M	
6.4.3.2	In-line valves and pumps	Low	L	L	L	ER
		Mod	M	M	M	
		High	M	M	M	
6.4.3.3	Flexible connections, expansion joints and seismic separations	Low	L	L	L	ER
		Mod	M	M	M	
		High	M	M	M	
6.4.3.4	Pipe Risers	Low	L	L	L	ER
		Mod	L	M	M	
		High	M	M	M	
6.4.3.5	Floor-mounted supports	Low	L	L	L	ER
		Mod	L	M	M	
		High	M	M	M	
6.4.3.6	Roof-mounted supports	Low	L	L	L	ER
		Mod	L	M	M	
		High	M	M	M	
6.4.3.7	Wall-mounted supports	Low	L	L	L	ER
		Mod	M	M	M	
		High	M	M	M	
6.4.3.8	Penetrations	Low	L	L	L	ER
		Mod	M	M	M	
		High	M	M	M	
6.4.4	Fire Protection Piping					
6.4.4.1	Suspended fire protection piping	Low	L	M	M	ER
		Mod	L	H	H	

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
		High	M	H	H	
6.4.5	Fluid Piping, not Fire Protection					
6.4.5.1	Hazardous materials	Low	L	L	L	ER
		Mod	H	H	H	
		High	H	H	H	
N/A	Fuel line	Low	L	L	L	
		Mod	H	H	L	
		High	H	H	M	
6.4.5.2	Nonhazardous materials	Low	L	L	L	ER
		Mod	M	M	M	
		High	M	M	M	
6.4.6	Ductwork					
6.4.6.1	Suspended Ductwork	Low	L	L	L	ER
		Mod	L	L	L	
		High	M	M	L	
6.4.6.2	Air diffuser	Low	L	L	L	NE, ER
		Mod	H	H	L	
		High	H	H	L	
6.4.7	Electrical and Communications Equipment					
6.4.7.1	Control panels, motor control centers and switchgear	Low	L	L	L	ER
		Mod	L	L	L	
		High	M	M	M	
6.4.7.2	Emergency generator	Low	L	L	M	ER
		Mod	L	M	H	
		High	L	H	H	
6.4.7.3	Transformers	Low	L	L	L	ER
		Mod	L	L	L	
		High	M	M	M	
6.4.7.4	Batteries and battery rack	Low	L	L	L	ER
		Mod	L	H	M	
		High	L	H	H	
6.4.7.5	Photovoltaic power systems (Solar panels)	Low	L	L	L	ER
		Mod	L	L	L	
		High	M	M	L	
6.4.7.6	Communication antennae	Low	L	L	L	ER

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
		Mod	L	M	L	
		High	M	H	M	
6.4.8	Electrical and Communications Distribution Equipment					
6.4.8.1	Electrical raceways, conduit, and cable trays	Low	L	L	L	ER
		Mod	L	M	M	
		High	M	M	M	
6.4.8.2	Distribution panels	Low	L	L	L	ER
		Mod	L	L	L	
		High	M	M	M	
6.4.9	Light Fixtures					
6.4.9.1	Recessed	Low	L	L	L	PR
		Mod	H	L	L	
		High	H	M	M	
6.4.9.2	Surface-mounted lighting	Low	L	L	L	PR
		Mod	H	L	L	
		High	H	M	M	
6.4.9.3	Pendant light fixtures	Low	L	L	L	NE
		Mod	H	L	L	
		High	H	M	M	
6.4.9.4	Heavy light fixtures	Low	L	L	L	NE
		Mod	H	L	L	
		High	H	M	M	
N/A	Exterior lighting	Low	L	L	L	
		Mod	M	L	L	
		High	M	M	M	
6.4.10	Elevators and Escalators					
6.4.10.1	Hydraulic Elevator (cab and elevator equipment)	Low	L	L	L	ER
		Mod	L	M	M	
		High	M	M	M	
6.4.10.2	Traction Elevator (elevator cab)	Low	L	L	L	ER
		Mod	L	M	M	
		High	M	M	M	
N/A	Cables, counterweights and guide rails (for cable-traction system)	Low	L	L	L	

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail		
		Mod	H	M	M			
		High	H	M	M			
N/A	Elevator motor and motor control cabinets	Low	L	L	L			
		Mod	L	M	M			
		High	L	H	M			
6.4.10.3	Escalator	Low	L	L	L	ER		
		Mod	L	M	L			
		High	L	M	L			
6.4.11	Conveyors							
6.4.11.1	Conveyors	Low	L	L	L	ER		
		Mod	L	M	M			
		High	M	M	M			
6.5 Furniture, Fixtures, & Equipment								
6.5.1 Storage racks								
6.5.1.1	Light duty shelving	Low	L	L	L	NE, ER		
		Mod	H	M	M			
		High	H	M	M			
6.5.1.2	Industrial storage racks	Low	L	L	L	ER		
		Mod	H	M	M			
		High	H	M	M			
6.5.2 Bookcases, Shelving								
6.5.2.1	Bookshelves	Low	L	L	L	NE		
		Mod	H	M	M			
		High	H	M	M			
6.5.2.2	Library and other shelving	Low	L	L	L	ER		
		Mod	H	M	M			
		High	H	M	M			
6.5.3 Computer & Communications Equipment								
6.5.3.1	Computer access floors	Low	L	L	L	ER		
		Mod	L	L	M			
		High	L	M	M			
N/A	Large computer equipment	Low	L	L	L			
		Mod	L	M	M			
		High	M	H	M			
N/A	Computer networks, data storage	Low	L	L	L			

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
		Mod	L	M	H	
		High	L	H	H	
N/A	Computer cabling	Low	L	L	L	
		Mod	L	L	L	
		High	L	L	L	
6.5.3.2	Computer and communication racks	Low	L	L	L	NE
		Mod	L	H	M	
		High	M	H	M	
6.5.3.3	Desktop computers and accessories	Low	L	L	L	NE
		Mod	L	H	M	
		High	L	H	M	
6.5.3.4	Television and video monitors, cameras, wall-mounted	Low	L	L	L	NE
		Mod	H	H	L	
		High	H	H	L	
N/A	Suspended speakers in conference room or auditorium	Low	L	L	L	
		Mod	M	M	L	
		High	H	H	L	
6.5.4	Hazardous materials storage					
6.5.4.1	Hazardous materials storage, cabinet and contents	Low	L	L	L	NE
		Mod	H	M	H	
		High	H	M	H	
N/A	Chemical, laboratory, medical supplies	Low	L	L	L	
		Mod	H	M	L	
		High	H	M	M	
N/A	Asbestos	Low	L	M	M	
		Mod	L	H	H	
		High	L	H	H	
6.5.5	Miscellaneous FF&E					
6.5.5.1	File cabinets, tall vertical or lateral files	Low	L	L	L	NE
		Mod	M	M	M	
		High	H	M	M	

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
6.5.5.2	Demountable partitions	Low	L	L	L	NE
		Mod	L	L	L	
		High	M	M	M	
6.5.5.3	Miscellaneous furniture	Low	L	L	L	NE
		Mod	M	M	L	
		High	H	M	L	
N/A	Miscellaneous furnishings	Low	L	L	L	
		Mod	L	M	L	
		High	L	M	L	
N/A	Large kitchen or laundry equipment	Low	L	L	L	
		Mod	M	M	L	
		High	H	H	M	
N/A	Lockers, vending machines	Low	L	L	L	
		Mod	H	M	L	
		High	H	M	L	
N/A	Freestanding wood stove (wood, pellet, or gas-fired)	Low	L	L	L	
		Mod	L	L	L	
		High	M	M	M	
6.5.6 Miscellaneous Contents						
6.5.6.1	Shelf-mounted items	Low	L	L	L	NE
		Mod	M	M	L	
		High	H	M	M	
N/A	Especially valuable or fragile merchandise	Low	L	M	L	
		Mod	L	H	L	
		High	L	H	L	
N/A	Drawer and cabinet latches (kitchen, laboratory, office, etc.)	Low	L	L	L	
		Mod	L	L	L	
		High	L	M	M	
N/A	Potted plants or indoor landscaping resting on shelves above the floor	Low	L	L	L	
		Mod	L	L	L	
		High	M	L	L	
6.5.6.2	Desktop, countertop items	Low	L	L	L	NE

Example No.	Example Name	Shaking Intensity	Life Safety (LS)	Property Loss (PL)	Functional Loss (FL)	Type of Detail
		Mod	L	M	L	
		High	L	H	M	
6.5.6.3	Fragile artwork	Low	L	L	L	NE
		Mod	L	H	L	
		High	L	H	L	
N/A	Tall sculptures (over 5 ft)	Low	L	L	L	
		Mod	M	M	L	
		High	H	H	L	
6.5.6.4	Fire extinguisher and cabinet	Low	L	L	L	NE
		Mod	M	H	L	
		High	M	H	L	

F. LIST OF RESOURCES RELATED TO NONSTRUCTURAL COMPONENTS

This appendix is a list of available resources related to nonstructural components, including codes and standards, testing protocols, guidance documents, nonproprietary details, photos, sample specifications, proprietary details, products, and research efforts. This list originates from Appendix B of the ATC-69 Report, *Reducing the Risks of Nonstructural Earthquake Damage, State-of-the-Art and Practice Report*, prepared by the Applied Technology Council for FEMA (ATC, 2008).

The information in this appendix is organized into the following tables:

Table F-1	Codes and Standards Related to Nonstructural Components	F-2
Table F-2	Guidance Documents Related to Nonstructural Components	F-10
Table F-3	Nonproprietary Details and Other Resources for Nonstructural Components	F-23
Table F-4	Proprietary Details and Products for the Protection of Nonstructural Components	F-32
Table F-5	Recent and Ongoing Research Related to Nonstructural Components	F-37

Table F-1 Codes and Standards Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
ACI 318-08	Building Code Requirements for Reinforced Concrete and Commentary	2008	Appendix D	Appendix on requirements for anchorage in concrete; published by the American Concrete Institute, Detroit, Michigan.
ACI 355.2-07	Qualification of Post-Installed Mechanical Anchors in Concrete	2007		Published by the American Concrete Institute, Detroit, Michigan.
ASCE/SEI 7-05	Minimum Design Loads for Buildings and Other Structures	2005	Chapter 13	Chapter specifying seismic design requirements for nonstructural components; published by the American Society of Civil Engineers, Reston, Virginia.
SEI/ASCE 31-03	Seismic Evaluation of Existing Buildings	2003	Sections 3.9, 4.2.7, 4.8, and Table 4-9	Successor document to FEMA 310 <i>Handbook for the Seismic Evaluation of Buildings – A Prestandard</i> . Relevant sections describe evaluation procedures for existing nonstructural components. Includes comprehensive checklists of potential nonstructural hazards. Published by the American Society of Civil Engineers, Reston, Virginia.

Table F-1 Codes and Standards Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
ASCE/SEI 41-06	Seismic Rehabilitation of Existing Buildings	2007	Chapter 11	Successor document to FEMA 356 <i>Prestandard and Commentary for the Seismic Rehabilitation of Buildings</i> . Relevant chapter describes design procedures for the rehabilitation of existing nonstructural components, and a table identifying nonstructural component types and their applicability to different performance objectives. Published by the American Society of Civil Engineers, Reston, Virginia.
ASCE/SEI 43-05	Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities	2005		Provides design criteria for structures, systems, and components in nuclear facilities, with the goal of ensuring that these facilities can withstand the effects of earthquake ground shaking at the desired level of performance. Published by the American Society of Civil Engineers, Reston, Virginia.
ASHRAE SPC 171P	Method of Test of Seismic Restraint Devices for HVAC&R Equipment	2006		Establishes methods of testing and documenting the working shear and tensile strength of seismic restraint devices that are integral with vibration isolators or resilient devices. Published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia.
ASTM E580/E580M-06	Standard Practice for Application of Ceiling Suspension Systems for Acoustical Tile and Lay-In Panels in Areas Requiring Seismic Restraint	2006		Standard for Zone 2; could also be used for Zones 3 and 4. Published by ASTM International, West Conshohocken, Pennsylvania.

Table F-1 Codes and Standards Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
Bulletin 2004-014-BU (Vancouver)	Seismic Restraint of Nonstructural Components	2004		Addresses suspended ceilings and non-load bearing partitions. Published by the City of Vancouver, British Columbia.
CSA S832-06 (Canada)	Seismic Risk Reduction of Operational and Functional Components (OFCs) of Buildings	2006		Operational and functional components (OFCs) is a Canadian term for nonstructural components. The second edition of a document first published in 2001. Describes how to identify and evaluate hazards caused by nonstructural components, and provides strategies to mitigate damage. Intended to be applicable to most buildings types, either new or existing, and intended for building owners, inspectors, facility managers, engineers, architects and others whose focus is to provide safety, serviceability and durability of nonstructural components when subjected to earthquakes. Published by the Canadian Standard Association, Mississauga, Ontario.

Table F-1 Codes and Standards Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
E.030 (Peru)	National Construction Code, Technical Standard for Buildings, E.030 Earthquake-Resistant Design	2003		Design requirements for buildings in Peru. Drift provisions changed in 1997, and are now among the most stringent in the world. Drift must be computed without an R factor, and allowable drift is limited to .007h for reinforced concrete, and .01h for steel structures. Standard school construction must be confined concrete, and masonry infill must be isolated from the concrete frame. Schools built since 1997 meeting these criteria have suffered virtually no damage in recent large earthquakes in Peru. Published by El Servicio Nacional de Normalización, Capacitación e Investigación para la Industria de la Construcción (SENCICO), Lima, Perú.
EN 1998-1:2004(E) (Europe)	Eurocode 8: Design of Structures For Earthquake Resistance (English version, Final Draft)	2004	Part 1, Sections 4.3.5, 4.3.6	Includes general rules, seismic actions, and rules for buildings. Relevant sections cover design of nonstructural elements and additional measures for masonry infilled frames. Non-structural elements mentioned include parapets, gables, antennae, mechanical appendages and equipment, curtain walls, partitions, and railings. Nonstructural elements that might cause risks to persons, affect the main structure, or disrupt services of critical facilities must be verified to resist seismic design actions. Designs for nonstructural elements of great importance are based on realistic models of the structure and on appropriate response spectra derived from the response of the supporting structural elements. Lateral force calculations include consideration of period ratio, importance factor, and behavior factor. Published by the European Committee for Standardization (CEN).

Table F-1 Codes and Standards Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
IBC 2006	2006 International Building Code	2006		National model building code, latest edition; scheduled for adoption in most jurisdictions across the United States. Specifically references ASCE 7-05 for design of nonstructural components. Published by the International Code Council, Washington, D.C.
IBC 2003	2003 International Building Code	2003		National model building code; adopted in some areas of the United States. Published by the International Code Council, Washington, D.C.
ICC-ES AC-156	Acceptance Criteria for Seismic Qualification by Shake-Table Testing of Nonstructural Components and Systems.	2004		Published by the International Code Council Evaluation Service, Whittier, California.
NFPA 13	Standard for the Installation of Sprinkler Systems, 2007 Edition	2007		Published by the National Fire Protection Association, Quincy, Massachusetts.

Table F-1 Codes and Standards Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
NCh 433.Of96 (Chile)	Chilean Norm NCh 433.Of96, Earthquake Resistant Design of Buildings	1996		Chilean code for buildings. Includes the following drift criteria: (1) drift must be computed without an R factor; and (2) must be less than 0.002h for buildings with precast shear walls with dry joints; less than 0.003h for shear wall building with rigidly attached masonry infill; less than .0075h for unbraced frames with isolated infill; and less than .015h for other structures. Includes a scale factor Q/Q_{min} that allows a reduction of the computed drift for longer period structures where the design base shear Q is less than a minimum base shear Q_{min} . Stringent drift criteria (more stringent than U.S. codes) have resulted in an almost exclusive use of shear wall systems in buildings. As a result, drift-related nonstructural damage is significantly reduced. Published by the Instituto Nacional de Normalizacion (INN-Chile), Santiago, Chile.
NCh 2369.Of2003 (Chile)	Chilean Norm NCh2369, Earthquake Resistant Design of Industrial Structures and Facilities	2003		Chilean code for industrial buildings. Includes recommendations and design rules for mechanical equipment that could be applicable to other types of buildings. Currently only available in Spanish. Published by the Instituto Nacional de Normalizacion (INN-Chile), Santiago, Chile.
UBC 1961	Uniform Building Code, 1961 Edition	1961		First appearance of separate provisions for nonstructural components in the UBC; maximum lateral force of 0.2g in Zone 3.
UBC 1976	Uniform Building Code, 1976 Edition	1976		Nonstructural provisions updated in response to 1971 San Fernando Earthquake; maximum force increased to 0.3g in Zone 4.

Table F-1 Codes and Standards Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
UBC 1988	Uniform Building Code, 1988 Edition	1988		Update of nonstructural provisions to consider response of non-rigid items and items at grade; maximum force remained 0.3g in Zone 4 for rigid items.
UBC 1997	Uniform Building Code, 1997 Edition	1997		Nonstructural seismic requirements are a blend of requirements from the 1994 and 1997 <i>NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures</i> .
USACE TI 809-04	Tri-Service Manual, Seismic Design for Buildings	1998	Chapter 10	Successor document to TM 5-809-10 and TM 5-809-10-1. Published by the US Army Corps of Engineers, Washington, D.C.
USACE TM 5-809-10	Tri-Service Manual, Seismic Design for Buildings	1996	Chapter 8, Appendix L	Provides a dynamic analysis procedure for design of nonstructural components that must remain functional after a major earthquake. Requires generation of floor response spectra and consideration of inter-story drift at the location of essential equipment. Appendix includes four design examples. Published by the US Army Corps of Engineers, Washington, D.C.

Table F-1 Codes and Standards Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
USACE TM 5-809-10-1	Tri-Service Manual, Seismic Design Guidelines for Essential Buildings	1986	Chapter 6	Provides methodology for design; defines essential nonstructural systems (Table 6-3); defines two levels of earthquake ground motion (EQ-I and EQ-II); requires equipment certification. Published by the US Army Corps of Engineers, Washington, D.C.
USACE TM-5-809-10-2	Tri-Service Manual, Seismic Design Guidelines for Upgrading Existing Buildings	1988	Chapter 9	Chapter focuses on improving performance of existing nonstructural installations. Includes a list of nonstructural systems with descriptions of potential damage and failure modes (Table 9-1). Published by the US Army Corps of Engineers, Washington, D.C.
VISCMA 102-07	Static Qualification Standards for Obtaining a VISCMA Compliant Seismic Component Rating	2007		Testing protocol for mechanical, electrical and plumbing equipment. Published by the Vibration Isolation and Seismic Control Manufacturers Association, Wayne, Pennsylvania.

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
ASHRAE RP-812	A Practical Guide to Seismic Restraint	1999		Published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia.
ASHRAE /SMACNA	Seismic Restraint Applications CD-ROM	2002		Provides technical information for design and installation of seismic restraints for HVAC equipment, piping, and ducts. Includes representative bracing details, layout examples, and tables. Consists of portions of the following documents: SMACNA's Seismic Restraint Manual: Guidelines for Mechanical Systems; ASHRAE's Handbook - HVAC Applications (2003); and ASHRAE's A Practical Guide to Seismic Restraint. Produced by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. and the Sheet Metal and Air Conditioning Contractors' National Association.
CISCA 1991	Recommendations for Direct-Hung Acoustical and Lay-in Panel Ceilings, Seismic Zones 0-2	1991		Industry standards for ceilings in low seismic zones. Published by Ceilings and Interior Systems Construction Association, Deerfield, Illinois.
CISCA 1990	Recommendations for Direct-Hung Acoustical and Lay-in Panel Ceilings, Seismic Zones 3-4	1990		Industry standards for ceilings in high seismic zones. Published by Ceilings and Interior Systems Construction Association, Deerfield, Illinois.

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
DGS, DSA (California)	Guide and Checklist for Nonstructural Earthquake Hazards in California Schools			Identifies potential hazards associated with nonstructural components and provides recommendations to mitigate hazards. Includes typical details and a nonstructural earthquake hazards checklist. Published by the California State Department of General Services, Division of the State Architect, and the Governor's Office of Emergency Services, Sacramento, California.
DOISSP	Nonstructural Hazards Rehabilitation Guidelines; Vol. I; Guidelines Usage, Architectural, Mechanical, Electrical, Plumbing			Contains guidance gathered from various sources, both public and private sources. Includes both proprietary and non-proprietary details. Published by the Department of the Interior Bureau of Reclamation, Seismic Safety Program (DOISSP), Washington, D.C.
DOISSP	Nonstructural Hazards Rehabilitation Guidelines; Vol. II; Furnishings, Interior Equipment, Miscellaneous Components, Mobile Homes, Manufactured Homes, FEMA 273, FEMA 310, FEMA 178, & ASCE 31-xx Excerpts			Contains guidance gathered from various sources, both public and private sources. Includes both proprietary and non-proprietary details. Published by the Department of the Interior Bureau of Reclamation, Seismic Safety Program (DOISSP), Washington, D.C.

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
EERI 84-04	Nonstructural Issues of Seismic Design and Construction	1984		Results of workshop including invited papers on nonstructural issues. Published by the Earthquake Engineering Research Institute, Oakland, California.
FEMA	Instructor's Guide for Nonstructural Earthquake Mitigation for Hospitals and other Health Care facilities.	1988		Materials for course given by Emergency Management Institute, Emmitsburg, Maryland.
FEMA	Final Report, Nonstructural Earthquake Mitigation Guidance Manual.	2004		Based on FEMA Region X Earthquake Hazard Mitigation Handbook for Public Facilities, 2002. Includes flowcharts, step-by-step procedures and some details. Divides nonstructural components into four groups: contents, exterior building elements, interior building elements, and building utilities. Prepared by URS Group, Inc. for FEMA.
FEMA Region X	Earthquake Hazard Mitigation Handbook for Public Facilities	2002		Available at http://www.conervationtech.com/FEMA-WEB/FEMA-subweb-EQ/index.htm
FEMA 74	Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide. Third Edition	1994		Successor document to previous editions of FEMA 74, first published in 1985.

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 74-FM	Earthquake Hazard Mitigation for Nonstructural Elements, Field Manual	2005		Includes three types of details: Non-Engineered, Prescriptive, and Engineered. Contains more details than FEMA 74, along with a field data sheet based on the FEMA 74 checklist.
FEMA 150	Seismic Considerations: Health Care Facilities	1990		Published by the Federal Emergency Management Agency, Washington, D.C.
FEMA 172	NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings	1992	Chapters 5, 6	Relevant chapters include details for electrical cabinets, chimneys, parapets, masonry partitions, raised access floors, and mechanical equipment.
FEMA 178	NEHRP Handbook for the Seismic Evaluation of Existing Buildings	1992	Section 10.5	Predecessor document to FEMA 310.
FEMA 232	Homebuilders' Guide to Earthquake-Resistant Design and Construction	2006		Includes details based on the 1994 edition of FEMA 74.

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 273	NEHRP Guidelines for the Seismic Rehabilitation of Buildings	1997		Predecessor document to FEMA 356.
FEMA 310	Handbook for the Seismic Evaluation of Buildings - A Prestandard	1998	Sections 3.9, 4.2.7, 4.8, and Table 4-9	Predecessor document to SEI/ASCE 31-03. Relevant sections describe evaluation procedures for existing nonstructural components. Includes comprehensive checklists of potential nonstructural hazards.
FEMA 356	Prestandard and Commentary for the Seismic Rehabilitation of Buildings	2000	Chapter 11	Successor document to FEMA 273/274, and predecessor to ASCE/SEI 31-03. Relevant chapter describes design procedures for the rehabilitation of existing nonstructural components, and a table identifying nonstructural component types and their applicability to different performance objectives.
FEMA 389	Communicating with Owners and Managers of New Buildings on Earthquake Risk: A Primer for Design Professionals	2004		

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 395	Incremental Seismic Rehabilitation of School Buildings (K-12): Providing Protection to People and Buildings	2003		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-21) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to school occupancies.
FEMA 396	Incremental Seismic Rehabilitation of Hospital Buildings: Providing Protection to People and Buildings	2003		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-23) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to hospital occupancies.
FEMA 397	Incremental Seismic Rehabilitation of Office Buildings: Providing Protection to People and Buildings	2003		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-24) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to office occupancies.
FEMA 398	Incremental Seismic Rehabilitation of Multifamily Apartment Buildings: Providing Protection to People and Buildings	2004		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-22) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to multifamily apartment occupancies.

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 399	Incremental Seismic Rehabilitation of Retail Buildings: Providing Protection to People and Buildings	2004		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-22) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to retail occupancies.
FEMA 400	Incremental Seismic Rehabilitation of Hotel and Motel Buildings	2005		Includes a table of "Nonstructural Seismic Performance Improvements" (page C-23) that lists possible seismic performance improvements that could be undertaken on nonstructural components common to hotel and motel occupancies.
FEMA 412	Installing Seismic Restraints for Mechanical Equipment	2002		Includes numerous elaborate details and many recommendations for seismic restraint of mechanical equipment.
FEMA 413	Installing Seismic Restraints for Electrical Equipment	2004		Includes numerous elaborate details and many recommendations for seismic restraint of electrical equipment.
FEMA 414	Installing Seismic Restraints for Duct and Pipe	2004		Includes numerous elaborate details and many recommendations for seismic restraint of duct and piping components.
FEMA 424	Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds	2004		Includes pictures of nonstructural damage (pages 4-17 through 4-19, 4-23, 4-24, 4-30, 4-31); a list of types of nonstructural components (page 4-59); graphics for ceilings, shelves, and walls (pages 4-60 and 4-61).

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 433	Using HAZUS-MH for Risk Assessment: How-To Guide	2004		
FEMA 445	Next-Generation Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings	2006	Section 4.2	Describes how performance-based seismic design guidelines will be developed under the ATC-58 Project. Section 4.2 refers specifically to the development of nonstructural performance products.
FEMA 450	NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, Part 1 and 2: Provisions and Commentary	2004	Chapters 6, 6A, and Commentary	Provides criteria for the design and construction of structures to resist earthquake ground motions. Relevant chapters include prescriptive requirements for the design of architectural, mechanical, electrical and piping components.
FEMA 452	A How-To Guide to Mitigate Potential Terrorist Attacks Against Buildings	2005		

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 454	Designing for Earthquakes: A Manual for Architects	2006	Section 6.6, Chapter 9	Discussion of code issues including nonstructural issues. Contains a collection of photos and generic details borrowed from various sources including: FEMA 74; details developed for the Lawrence Livermore National Lab; and the SMACNA Guidelines. Includes a discussion on the need for systems engineering, considering all parts of the building as a whole. Provides a checklist (Table 9-3) showing allocation of design responsibilities for nonstructural systems and components.
FEMA 460	Seismic Considerations for Steel Storage Racks Located in Areas Accessible to the Public	2005		Includes: a review of the performance of storage racks in past earthquakes; a history of the development of codes and standards used for storage rack design; current storage rack design practices; guidance on recommended performance goals and design requirements for storage racks; guidelines for implementation/responsibilities associated with the specification, procurement, and installation of pallet storage racks; suggested guidance for securing contents; recommendations for operations and use; suggested guidance for quality assurance programs; a discussion of current and past storage rack research and testing; suggestions for post-earthquake inspections; and proposed modifications to seismic design provisions and standards for racks.

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
FEMA 461	Interim Protocols for Determining Seismic Performance Characteristics of Structural and Nonstructural Components	2007		Provides an interim protocol for testing of building components to establish their performance capability in the form of fragility functions. Fragility functions are used to assess the seismic performance of individual components, systems incorporating these components, and buildings containing these systems and components that are subjected to earthquake shaking. Protocols are not intended for seismic performance qualification testing of nonstructural components required by the building code, although the loading protocols could be used for that purpose.
FEMA 577	Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings	2007		
FEMA 582	Design Guide for Improving Commercial Buildings Safety in Earthquakes, Floods, and High Winds	Future		

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
John Wiley & Sons, Inc.	Earthquakes, an Architect's Guide to Nonstructural Seismic Hazards	1990		Target audience is architects. Written by H.J. Lagorio. Published by John Wiley & Sons, Inc., New York, New York.
OCIPEP (Canada)	Seismic Hazard Assessment and Mitigation for Buildings' Functional and Operational Components: A Canadian Perspective	2002		Contains figures and photos from various sources, including FEMA 74. Includes damage photos from 1999 Chi Chi, Taiwan Earthquake: damage to rooftop equipment (page 19); collapse of free-standing non-structural wall (page 20); and damage to sprinkler systems. Prepared by the Department of Civil Engineering, University of Ottawa, for the Office of Critical Infrastructure Protection and Emergency Preparedness (OCIPEP), Ontario, Canada.
Oregon Emergency Management	Earthquake Preparedness and Mitigation Guidance for Oregon State Agency Offices and Warehouses	2004		Focuses on office and warehouse occupancies, with special attention to storage racks. Includes photos and guidance including shrink-wrap and netting to mitigate potential falling hazards. Provides some specific information on performance of furniture by specific vendors (Hayworth, Steelcase, and Artmet).
Pan American Health Organization	Principles of Disaster Mitigation in Health Facilities	2000	Chapter 3	Includes guidance on assessing and mitigating seismic vulnerabilities of nonstructural components. Published by the Pan American Health Organization, Regional Office of the World Health Organization, Washington, D.C.

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
Salt Lake City School District	Seismic Design Criteria of Nonstructural Systems For New School Facilities And Existing School Facilities	2001		Developed under a FEMA "Project Impact" Grant. Intended for use on new school design projects and seismic retrofit projects in the Salt Lake City School District. Establishes minimum design procedures, general detailing requirements, design approval procedures, and construction inspection procedures for nonstructural items. The design engineer or architect is responsible for development of project specific nonstructural details. Some requirements exceed the minimum standards given in the Uniform Building Code (UBC).
Seattle Public Schools	School Facilities Manual: Nonstructural Protection Guide. Safer Schools, Earthquake Hazards, Nonstructural. Second Edition	2000		Includes detailed inventory form and details not included in FEMA 74.
University of California, Berkeley	UC Berkeley: Q-Brace Quake Bracing Guidelines	2005		Guidelines developed for University of California, Berkeley campus facilities. Includes detailed solutions for contents identifying vendor supplied products or size of hardware to use.
USACERL TR-98/34	Seismic Mitigation for Equipment at Army Medical Centers	1998		Presents simple methods for reducing the seismic vulnerability of equipment at Army medical centers. Illustrations, observations, and recommendations are based on examples from Madigan Army Medical Center (MAMC). Concerns about particular well-anchored critical medical equipment are presented. Published by the U.S.

Table F-2 Guidance Documents Related to Nonstructural Components (continued)

Document Number/Source	Title	Publication Date	Relevant Sections	Comments
				Army Construction Engineering Research Laboratories.
USACE, Engineering and Support Center	Seismic Protection for Mechanical Equipment			Presentation on procedures to design seismic supports of equipment, piping, and ducts; includes force coefficients and methods to calculate forces. Also includes a list of references useful as guidelines for the design. Available from the U.S. Army Corps of Engineers at http://www.dtic.mil/ndia/2005triservice/track16/stut.pdf .
VISCMA	Understanding the 2000 IBC Code (Architectural Components and Equipment Restraint)	2005		Available on the Vibration Isolation and Seismic Control Manufacturers Association website at http://www.viscma.com/articles.htm
VISCMA	The Pitfalls of Combining Internal & External Equipment Isolation	2003		Explains problems associated with utilizing both internal and external isolation in equipment. Shows that performance is better if only external isolation is used. Available on the Vibration Isolation and Seismic Control Manufacturers Association website at http://www.viscma.com/articles.htm

Table F-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
ASHRAE /SMACNA	Non-proprietary Details	Seismic Restraint Applications CD-ROM	2002		Provides technical information for design and installation of seismic restraints for HVAC equipment, piping, and ducts. Includes representative bracing details, layout examples, and tables. Consists of portions of the following documents: SMACNA's Seismic Restraint Manual: Guidelines for Mechanical Systems; ASHRAE's Handbook - HVAC Applications (2003); and ASHRAE's A Practical Guide to Seismic Restraint. Produced by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. and the Sheet Metal and Air Conditioning Contractors' National Association.
ATC-38	Damage Inventory Form	ATC-38 Postearthquake Building Performance Assessment Form and Surveyor Instructions	2001		10-page form and instructions that provides standardized damage percentages and standardized codes for ceilings and partitions. Available with the ATC-38 Project report, or on the EERI website at http://www.eeri.org/
Dartmouth College	Sample Specification	Dartmouth College Design & Construction Guidelines, Section 15240 Seismic Restraint and Vibration Control	2004		Specification for the installation of equipment at Dartmouth College. Available at http://www.dartmouth.edu/~opdc/pdfs/15240.pdf

Table F-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
DCS, DSA (California)	Guide and Checklist	Guide and Checklist for Nonstructural Earthquake Hazards in California Schools	2003		Identifies potential hazards associated with nonstructural components and provides recommendations to mitigate hazards. Includes typical details and a nonstructural earthquake hazards checklist. Published by the California State Department of General Services, Division of the State Architect, and the Governor's Office of Emergency Services, Sacramento, California.
DOISSP	Non-proprietary Details	Nonstructural Hazards Rehabilitation Guidelines; Vol. I; Guidelines Usage, Architectural, Mechanical, Electrical, Plumbing	2003		Contains guidance gathered from various sources, both public and private sources. Includes both proprietary and non-proprietary details. Published by the Department of the Interior Bureau of Reclamation, Seismic Safety Program (DOISSP), Washington, D.C.
DOISSP	Non-proprietary Details	Nonstructural Hazards Rehabilitation Guidelines; Vol. II; Furnishings, Interior Equipment, Miscellaneous Components, Mobile Homes, Manufactured Homes, FEMA 273,	2003		Contains guidance gathered from various sources, both public and private sources. Includes both proprietary and non-proprietary details. Published by the Department of the Interior Bureau of Reclamation, Seismic Safety Program (DOISSP), Washington, D.C.

Table F-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
		FEMA 310, FEMA 178, & ASCE 31-xx Excerpts			
EERI	Damage Inventory Form	EERI Reconnaissance/ Clearinghouse Report Form - Architectural and Nonstructural Elements	2000		2-page form consisting of broad categories, several subcategories, and blank lines to report damage and gather damage statistics.
FEMA	Non-proprietary Details	Final Report, Nonstructural Earthquake Mitigation Guidance Manual	2004		Based on FEMA Region X Earthquake Hazard Mitigation Handbook for Public Facilities, 2002. Includes flowcharts, step-by-step procedures and some details. Divides nonstructural components into four groups: contents, exterior building elements, interior building elements, and building utilities. Prepared by URS Group, Inc. for FEMA.

Table F-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
FEMA Region X	Non-proprietary Details	Earthquake Hazard Mitigation Handbook for Public Facilities	2002		Available at http://www.conervationtech.com/FEMA-WEB/FEMA-subweb-EQ/index.htm
FEMA 74	Non-proprietary Details	Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide. Third Edition	1994		Successor document to previous editions of FEMA 74, first published in 1985.
FEMA 74 FM	Non-proprietary Details	FEMA 74 Field Manual	2005		Includes three types of details: Non-Engineered, Prescriptive, and Engineered. Contains more details than FEMA 74, along with a field data sheet based on the FEMA 74 checklist.
FEMA 172	Non-proprietary Details	NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings	1992	Chapters 5, 6	Relevant chapters include details for electrical cabinets, chimneys, parapets, masonry partitions, raised access floors, and mechanical equipment.
FEMA 412	Non-proprietary Details	Installing Seismic Restraints for Mechanical Equipment	2002		Includes numerous elaborate details and many recommendations for seismic restraint of mechanical equipment.

Table F-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
FEMA 413	Non-proprietary Details	Installing Seismic Restraints for Electrical Equipment	2004		Includes numerous elaborate details and many recommendations for seismic restraint of electrical equipment.
FEMA 414	Non-proprietary Details	Installing Seismic Restraints for Duct and Pipe	2004		Includes numerous elaborate details and many recommendations for seismic restraint of duct and piping components.
FEMA 424	Photos, Damage	Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds	2004		Includes pictures of nonstructural damage (pages 4-17 through 4-19, 4-23, 4-24, 4-30, 4-31); a list of types of nonstructural components (page 4-59); graphics for ceilings, shelves, and walls (pages 4-60 and 4-61).
FEMA 454	Non-proprietary Details	Designing for Earthquakes: A Manual for Architects	2006	Section 6.6, Chapter 9	Discussion of code issues including nonstructural issues. Contains a collection of photos and generic details borrowed from various sources including: FEMA 74; details developed for the Lawrence Livermore National Lab; and the SMACNA Guidelines. Includes a discussion on the need for systems engineering, considering all parts of the building as a whole. Provides a checklist (Table 9-3) showing allocation of design responsibilities for nonstructural systems and components.

Table F-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
Los Alamos National Laboratory	Sample Specification	Section 22 0548 Vibration and Seismic Controls for Plumbing, Piping, and Equipment	2006		Specification for the anchorage of equipment at Los Alamos National Lab. Available at http://engstandards.lanl.gov/conspec/pdf/22_0548R0.pdf
OCIPEP (Canada)	Photos, Damage	Seismic Hazard Assessment and Mitigation for Buildings' Functional and Operational Components: A Canadian Perspective	2002		Contains figures and photos from various sources, including FEMA 74. Includes damage photos from 1999 Chi Chi, Taiwan Earthquake: damage to rooftop equipment (page 19); collapse of free-standing non-structural wall (page 20); and damage to sprinkler systems. Prepared by the Department of Civil Engineering, University of Ottawa, for the Office of Critical Infrastructure Protection and Emergency Preparedness (OCIPEP), Ontario, Canada.
Oregon Emergency Management	Non-proprietary Details	Earthquake Preparedness and Mitigation Guidance for Oregon State Agency Offices and Warehouses	2004		Focuses on office and warehouse occupancies, with special attention to storage racks. Includes photos and guidance including shrink-wrap and netting to mitigate potential falling hazards. Provides some specific information on performance of furniture by specific vendors (Hayworth, Steelcase, and Artmet).

Table F-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
PEER 2003/05	Taxonomy and Nonstructural Damage Inventory Form	Response Assessment of Nonstructural Building Elements	2003		Proposes a taxonomy (classification) of nonstructural elements by functionality, modes of failure, acceleration-sensitive or drift-sensitive response parameter, and repercussions of damage. Provides damageability, cost, and loss data for 200 elements. Includes a Nonstructural Damage Inventory Form used following the Nisqually Earthquake.
PEER 2003/12	Non-proprietary Details	Implementation Manual for the Seismic Protection of Laboratory Contents: Format and Case Studies	2003		Presents case studies for University of California Berkeley campus labs. Suggests format for User's Manual that could be used to help occupants install do-it-yourself details for a particular facility.
PEER 2005/03	Taxonomy	A Taxonomy of Building Components for Performance-Based Earthquake Engineering	2005		Provides a detailed taxonomy (classification) of nonstructural components. Each component is assigned a unique identification number. The list differentiates between anchored and unanchored versions of the same item.
Sandia	Sample Specification	Special Specification Section 13085S - Seismic Protection			Sample specification for the anchorage of equipment at Sandia (16 pages). Includes lists of equipment, detailed requirements, specific instructions for some items, load

Table F-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
					limits, and member sizes.
Seattle Public Schools	Non-proprietary Details	School Facilities Manual: Nonstructural Protection Guide. Safer Schools, Earthquake Hazards, Nonstructural. Second Edition	2000		Includes detailed inventory form and details not included in FEMA 74.
Southern California Earthquake Center	Photos, Damage	Nonstructural Issues in Public Schools - "Stairs to Nowhere"	2000		Photos of damage in school facilities in Southern California. Available at http://www.scec.org/instanet/00news/images/mcgavin/sld001.htm
University of California, Berkeley	Non-proprietary Details	UC Berkeley: Q-Brace Quake Bracing Guidelines	2005		Guidelines developed for University of California, Berkeley campus facilities. Includes detailed solutions for contents identifying vendor supplied products or size of hardware to use.

Table F-3 Nonproprietary Details and Other Resources for Nonstructural Components (continued)

Document Number/Source	Resource Type	Title	Publication Date	Relevant Sections	Comments
USACERL TR-98/34	Photos, Mitigation	Seismic Mitigation for Equipment at Army Medical Centers	1998		Presents simple methods for reducing the seismic vulnerability of equipment at Army medical centers. Illustrations, observations, and recommendations are based on examples from Madigan Army Medical Center (MAMC). Concerns about particular well-anchored critical medical equipment are presented. Published by the U.S. Army Construction Engineering Research Laboratories.
VISCMA 101-07	Sample Specification	Seismic Restraint Specification Guidelines for Mechanical, Electrical And Plumbing Systems	2007		Sample specification for seismic restraint of mechanical, electrical and plumbing equipment. Published by the Vibration Isolation and Seismic Control Manufacturer's Association, Wayne, Pennsylvania.

Table F-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)

Product Source/Vendor	Product or Service Description	Comments
Chatsworth Seismic Protection Products	Chatsworth Seismic Protection Products	Variety of seismic protection products. Available at http://www.twacomm.com/catalog/dept_id_644.htm
Flexhead	Flexible fire protection	Proprietary flexible connection for sprinklers heads. Available at http://www.flexhead.com/
Hilti	Concrete anchors and hardware	Information on product selection, different installation systems, and load data. Available at www.hilti.com
International Seismic Application Technology	International Seismic Application Technology (ISAT) Applications and Design Manual	Focuses exclusively on mechanical, electrical, plumbing equipment and piping. Includes load tables and details showing use of products. Available at www.isatsb.com
International Seismic Application Technology	2003 IBC Specification - Seismic Restraint of Suspended Utilities	Sample specification available at www.isatsb.com
Kinetics Noise Control	Kinetics noise control seismic restraint capabilities	Brochure presents restraint systems that serve to limit the movement of equipment during a seismic event. Available at http://www.kineticsnoise.com/hvac/pdf/seismic%20restraint%20capabilities.pdf
Loos & Co	Proprietary details approved by	Includes collections of details, such as: Section 7, Sway Brace Components, Installation

Table F-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)

Product Source/Vendor	Product or Service Description	Comments
	OSHPD for use in California hospitals	Instructions and Details. Available at www.earthquakebrace.com
Mason Industries	Details, Handbook, and online resources	Available at http://www.mason-ind.com/html/about.htm or http://209.200.80.33/html/seismic_engineering_index.htm
Metraflex	Thermal and seismic expansion joints for pipe	Available at http://www.metraflex.com/seismic_met.php
Pacific Seismic Products	ASCE 25-97 listed seismic actuated valves for residential, commercial and industrial applications	Gas shut off valves and other seismic actuated devices. Available at http://www.psp4gasoff.com/aboutpsp.htm
Ridg-U-Rak	Isolation system for storage racks	Isolation test of storage racks, both with and without transverse isolation. Movie of test available on website. Available at http://www.ridgurak.com
Technotes Issue No. 21 RWDI Consulting Engineers and Scientists	Base isolation system for museum pieces or equipment	"Seismic Protection of Museum Artifacts using Base Isolation," Bujar Myslimaj, Ph.D., P.Eng., Senior Specialist, Scott Gamble B.Sc., P.Eng., Principal, Ray Sinclair, Ph.D., Principal. Available at http://go.rwdi.com/technotes/t21.pdf

Table F-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)

Product Source/Vendor	Product or Service Description	Comments
Safety Central	Earthquake safety fasteners, furniture straps, and emergency preparedness supplies	Available at www.safetycentral.com
Secure Quick	Secure Quick Seismic Fastening System	Consists of steel cable, wall bracket, and cable fasteners for attaching furniture to wood stud walls. Also provided on website, "Why You Should Not Use Plastic Tabs Devices, Velcro, Hook and Loop, Nylon Straps or Metal Braces." Available at www.quakesecure.com
Secure-It	PC Security Hardware	Provides products to secure computer equipment. Intended as protection against theft, but security cables and hardware could also be adapted as seismic restraint for other desktop items. Available at http://www.secure-it.com/shop/index.php/cPath/21
Seismic Restraints NZ	Hardware and systems for contents: collectables, home, office, school, hospital, lab, and technology.	Available at www.seismicrestraints.co.nz
Seismic Solutions	Seismic restraint for ducts, pipes, cable trays, and equipment using cables	Services include structural design, labor and materials for installation. Available at http://www.seismicsolutionsinc.com/details.html

Table F-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)

Product Source/Vendor	Product or Service Description	Comments
Simpson Strong-Tie	Provides load rated straps and ties	Includes link for DIY (Do-it-Yourself) projects that illustrate the use of various connectors and adhesives, which could help with some nonstructural installations. Available at http://www.strongtie.com/products/categories/diy.html
Strand Earthquake Consultants	Engineering and products for nonstructural seismic mitigation	Distributors for GeoSIG, Pacific Seismic Products, Metraflex, and WorkSafe Technologies.
Taylor Devices, Inc.	Viscous dampers for equipment protection	Available at http://www.taylordevices.com/SeismicDampers.htm
The Preparedness Center	Earthquake safety fasteners, furniture straps, and emergency preparedness supplies	Available at www.preparedness.com
USG	"Seismic Ceiling Resource Center"	Includes a series of technical notes and guidelines related to ceilings, ceiling tracks, and shadow moldings. Available at www.usg.com and www.seismicceilings.com
Viking	Flexible connections for sprinkler heads	Available at http://www.vikingcorp.com/databook/sprinklers/spk_accessories/070605.pdf

Table F-4 Proprietary Details and Products for the Protection of Nonstructural Components (continued)

Product Source/Vendor	Product or Service Description	Comments
WorkSafe Technologies	System for base-isolation of equipment	IsoBase™ Seismic Isolation Platform, available at http://www.worksafetech.com/
WorkSafe Technologies	Large variety of products for seismic protection of nonstructural components in offices, data centers, hospitals, laboratories, and warehouses.	Available at http://www.worksafetech.com/

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
8NCEE-002034	Enhancing the Resilience of Acute Care Facilities: An Overview of MCEER Research	Filiatrault, A., et al.	2006	Paper at 8th National Conference on Earthquake Engineering, San Francisco, California.
13WCEE-00295	Overturning Criteria for Non-Anchored Non-Symmetric Rigid Bodies	Boroschek, R.L., and Romo, D.	2004	Theoretical discussion of the effect of non-symmetric bodies subjected to overturning. Paper at 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada.
ATC-29	Proceedings of a Seminar on Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures		1992	Includes information on seismic design, performance, and research pertaining to nonstructural components. Funded by the National Center for Earthquake Engineering Research and the National Science Foundation.
ATC-29-1	Proceedings of a Seminar on Seismic Design, Retrofit, and Performance of Nonstructural Components		1998	Includes information on seismic design, performance, and research pertaining to nonstructural components. Funded by the National Center for Earthquake Engineering Research and the National Science Foundation.

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
ATC-29-2	Proceedings of Seminar on Seismic Design, Performance, and Retrofit of Nonstructural Components in Critical Facilities		2003	Focused principally on nonstructural components and systems in facilities with critical functions. Includes information on the state of the art, state of the practice, and efforts needed to improve both. Prepared in cooperation with the Multidisciplinary Center for Earthquake Engineering Research, and funded by the National Science Foundation.
ATC-38	Database on the Performance of Structures Near Strong-Motion Recordings: 1994 Northridge, California, Earthquake		2001	Effort to correlate structural and nonstructural damage with ground motion parameters recorded during the 1994 Northridge Earthquake. Report includes a CD-ROM with Access database, Excel files, text files, and collection of over 500 photos. Database includes some nonstructural damage data in the following categories: "cladding separation or damage," "partitions damage," "windows damage," "lights and ceilings damage," and "Building Contents Damage." Most photos do not show damage, but provide an overview of the building from street. Report also includes the ATC-38 Postearthquake Building Performance Assessment Form and Surveyor Instructions. Nonstructural categories include Exterior Cladding/Glazing; Partitions; Ceilings; Plumbing, Electrical, Lighting, HVAC; Fire Protection; Major Fixed Equipment, Elevators, Chimneys, and Unusual Contents.
ATC-58	Proceedings: Mini-Workshop/Invited Meeting on the Identification of		2005	ATC-58 Project workshop focusing on the selection of a nonstructural component taxonomy, and identifying nonstructural components that are significant to the estimation of casualty, direct economic, and downtime

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
	Nonstructural Components of Significance			losses from earthquake damage.
ATC-58	Guidelines for Seismic Performance Assessment of Buildings, ATC-58 35% Complete Draft		2007	Interim report on methodology for seismic performance assessment of new and existing buildings. Methodology will be applicable to most common building types designed and constructed in the United States within the past 50 years, and will estimate losses in terms of causalities, direct economic losses, and downtime as a result of earthquake damage. Loss estimation is based on fragility curves, which will be provided for both structural and nonstructural components.
FEMA 349	Action Plan for Performance Based Seismic Design		2000	Predecessor document to FEMA 445. Prepared by the Earthquake Engineering Research Institute for FEMA.
FEMA 445	Next-Generation Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings	2006	Section 4.2	Describes how performance-based seismic design guidelines will be developed under the ATC-58 Project. Section 4.2 refers specifically to the development of nonstructural performance products.

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
EERI	Learning from Earthquakes: a Survey of Surveys.	Porter, K.	2002	Taken from an EERI Invitational Workshop: An Action Plan to Develop Earthquake Damage and Loss Data Protocols, September 19-20, 2002, Doubletree Hotel, Pasadena, California.
MCEER	ASHRAE Consortium Investigates Performance of Roof-Top Air Handling Unit		Future	MCEER's ASHRAE Consortium is beginning Phase II studies involving shake table testing of a rigidly anchored and vibration isolated roof-top air handling unit. Testing will begin in March 2008 in the Structural Engineering and Earthquake Simulation Laboratory (SEESL) at the University at Buffalo. Studies will focus on developing a specialized numerical model capable of analyzing the seismic response of various types of HVAC equipment mounted on ASHRAE-type isolation/restraint systems.
MCEER	Seismic Vulnerability and Protection of Nonstructural Components	T.T. Soong and D. Lopez Garcia	2003	Addresses seismic vulnerability and protection strategies. Divides nonstructural items into 3 categories: Unrestrained Nonstructural Components; Restrained Nonstructural components; and Nonstructural Systems, which consist of systems of nonstructural components. Cites examples of fragility curves developed for each category. Contains discussion of both damping systems and isolation systems as protection strategies. Ends with recommendations for 6 tasks: (1) Develop a Catalog of Nonstructural Components, Systems and Contents; (2) Identify Nonstructural Performance Measures; (3) Identify Engineering Demand Parameters; (4) Develop Damage Database; (5) Establish Comprehensive Testing and Certification Protocols; and (6) Performance Evaluation Case

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
				Studies/Test bed Checks.
MCEER-99-0014	MCEER Nonstructural Damage Database	Kao, A., and Soong, T.T.	1999	Database of earthquake damage to nonstructural elements.
MCEER-05-0005	"Simulation of Strong Ground Motions for Seismic Fragility Evaluation of Nonstructural Components in Hospitals"	Wanitkorkul, A. and Filiautault, A.	2005	Published by the Multidisciplinary Center for Earthquake Engineering Research, University at Buffalo, State University of New York.

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
MCEER-06-0001	Seismic Fragility of Suspended Ceiling Systems	Badillo-Almaraz, Whittaker, Reinhorn, Cimellaro	2006	Report on testing of Armstrong ceiling systems. Concludes that compression bars and retention clips help in the behavior of ceilings, and that undersized tiles are a detriment.
PEER 1998/05	Rocking Response and Overturning of Equipment Under Horizontal Pulse-Type Motions	N. Makris, Y. Roussos	1998	Published by the Pacific Earthquake Engineering Research Center, Berkeley, California.
PEER 1999/06	Rocking Response and Overturning of Anchored Equipment under Seismic Excitations	N. Makris, J. Zhang	1999	Results of shake table testing.
PEER 2001/14	Rocking Response of Equipment Anchored to a Base Foundation	N. Makris, C. Black	2001	Example of PEER research related to Lifelines. PEER has done series of tests funded by PG&E on electrical substation equipment including rigid bus connectors, flexible bus connectors, transformer bushings, and heavy substation equipment.
PEER 2002/01	Nonstructural Loss Estimation: The UC	M. Comerio,	2002	Case studies of loss estimation for five University of California Berkeley campus buildings. Includes a table (Table 10) showing costs assumed for

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
	Berkeley Case Study	J. Stallmeyer		many types of equipment, and photos of lab equipment.
PEER 2002/05	Guidelines, Specifications, and Seismic Performance Characterization of Nonstructural Building Components and Equipment	Filiatrault, A., Christopoulos, C, and Stearns, C.	2001	Contents include chapters on nonstructural earthquake damage. Nonstructural items are divided into 5 groups: contents; building service equipment; building utilization equipment; interior architectural elements; and exterior architectural elements. Overview of various design guidelines and inventory of previous analytical and experimental studies. Includes recommendations, and comprehensive list of references.
PEER 2003/05	Response Assessment of Nonstructural Building Elements	S. Taghavi, E. Miranda	2003	Proposes a taxonomy (classification) of nonstructural elements by functionality, modes of failure, acceleration-sensitive or drift-sensitive response parameter, and repercussions of damage. Provides damageability, cost, and loss data for 200 elements. Includes a Nonstructural Damage Inventory Form used following the Nisqually Earthquake.
PEER 2003/12	Implementation Manual for the Seismic Protection of Laboratory Contents: Format and Case Studies	W. Holmes, M. Comerio	2003	Presents case studies for University of California Berkeley campus labs. Suggests format for User's Manual that could be used to help occupants install do-it-yourself details for a particular facility.

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
PEER 2005/03	A Taxonomy of Building Components for Performance-Based Earthquake Engineering	Porter, Keith	2005	Provides a detailed taxonomy (classification) of nonstructural components. Each component is assigned a unique identification number. The list differentiates between anchored and unanchored versions of the same item.
PEER 2005/05	Performance Characterization of Bench- and Shelf-Mounted Equipment	S. Chaudhuri and T. Hutchinson	2005	
PEER 2005/07	Experimental and Analytical Studies on the Seismic Response of Freestanding and Anchored Laboratory Equipment	D. Konstantinidis, N. Makris	2005	Shake table testing of equipment.
PEER 2005/12	PEER Test bed Study on a Laboratory Building: Exercising Seismic Performance Assessment	M. Comerio	2005	Test bed performance assessment of the UC Science Building linking performance of contents to operational failure. Shows the interdependence of building structure, systems, and contents in performance assessment, and highlights where further research is needed.

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
SUNY Buffalo	Nonstructural Components Simulator (NCS).		Future	Specialized equipment for testing nonstructural components. University at Buffalo's NEES (UB-NEES) facility is commissioning a dedicated Nonstructural Component Simulator (NCS). The NCS is a modular and versatile two-level platform for experimental performance evaluation of nonstructural components and equipment under realistic full scale floor motions. NCS can provide the dynamic stroke necessary to replicate full-scale displacements, velocities and accelerations at the upper levels of multi-story buildings during earthquake shaking. Both displacement sensitive and acceleration sensitive nonstructural components and equipment can be experimentally evaluated under full-scale floor motions to understand, quantify and control their seismic response.
SUNY Buffalo, CSEE-SEESL-2004-02	"Shake Table Testing of Frazier Industrial Storage Pallet Racks"	Filiatrault, A. and Wanitkorkul, A.	2004	Published by the University at Buffalo, State University of New York, Buffalo, New York.
SUNY Buffalo, CSEE-SEESL-2005-01	"Seismic Qualification By Shake Table Testing of a Centrifugal Liquid Chiller according to AC-156 Testing Protocol"	Filiatrault, A. and Wanitkorkul, A.	2005	Published by the University at Buffalo, State University of New York, Buffalo, New York.

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
SUNY Buffalo, CSEE-SEESL-2005-03	"Shake Table Testing of Ridg-U-Rak Rigid Based and Ridg-U-Rak Patent Pending Base Isolated Industrial Storage Racks"	Filiatrault, A., Wanitkorkul, A. and Seo, J-M.	2005	Published by the University at Buffalo, State University of New York, Buffalo, New York.
SUNY Buffalo, CSEE-SEESL-2005-05	"Seismic Qualification of a Centrifugal Liquid Chiller by Shake Table Testing"	Filiatrault, A. and Wanitkorkul, A.	2005	Published by the University at Buffalo, State University of New York, Buffalo, New York.
SUNY Buffalo, CSEE-SEESL-2006-05	"Experimental Seismic Performance Evaluation of ASRAE-Type Isolation/Restraint Systems"	Fathali, S. and Filiatrault, A.	2006	Published by the University at Buffalo, State University of New York, Buffalo, New York.
SUNY Buffalo, CSEE-SEESL-2006-07	"Shake Table Testing of Ridg-U-Rak Rigid Based and Ridg-U-Rak Patent Pending Base Isolated Industrial Storage Racks: Production Unit Testing"	Filiatrault, A., and Wanitkorkul, A.	2006	Published by the University at Buffalo, State University of New York, Buffalo, New York.

Table F-5 Recent and Ongoing Research Related to Nonstructural Components (continued)

Document Number/Source	Title	Author(s)	Publication Date	Comments
SUNY Buffalo, CSEE-SEESL-2006-19	"Shake Table Testing of Ridg-U-Rak Rigid Based and Ridg-U-Rak Patent Pending Base Isolated Industrial Storage Racks: Final Production Unit Testing"	Filiatrault, A., and Wanitkorkul, A.	2006	Published by the University at Buffalo, State University of New York, Buffalo, New York.
University of Chile	Controlled Overturning of Unanchored Rigid Bodies	Boroschek, R.L., and Iruretagoyena, A.		Review of test results for equipment on an inclined surface. Results show that an incline can force overturning to occur in a preferred direction. For example, a 3-degree angle will result in an 89% probability that blocks will overturn in that direction. Could be useful information for keeping contents on shelves.

G. GLOSSARY

Air gap: For vibration isolated equipment, the air gap is the nominal clearance between the equipment support frame and the bumper restraint or snubber. Where the air gap exceeds 0.25", the seismic design force must be doubled ($2F_p$) per ASCE/SEI 7-10. The optimal size of this air gap is a subject of continuing study and laboratory testing.

Anchorage: Connection or attachment of a nonstructural component to the structure typically through the use of welding, bolts, screws, post-installed anchors or other mechanical fasteners that provide a positive connection. Based on the configuration and the deformability of the components used, the anchorage may behave as a rigid attachment or a flexible attachment.

Anchors in Concrete and Masonry: Anchors into concrete or masonry are required for the attachments of many nonstructural components. See ACI 318 Appendix D for requirements for anchors embedded in concrete. See TMS 402/ACI 503/ASCE 5 for anchors embedded in masonry. See also post-installed anchors and power actuated fasteners.

Appendage: An architectural component such as a canopy, marquee, ornamental balcony or statuary.

Base: The portion of a building embedded in or resting on the ground surface. Seismic forces are delivered to the base of a building. This term is also used to describe the interface of a freestanding nonstructural component with the floor or roof of a building where it is supported. Seismic forces from the floor or roof level of the building are delivered to the base of the nonstructural component.

Base Isolation: A method whereby a building superstructure is separated from its foundation using flexible bearings in order to reduce the earthquake forces. Special detailing is required to provide flexible connections for architectural components, building utilities, piping, etc. that cross the isolation plane into the building. This method can also be used to protect individual pieces of critical, sensitive, or expensive equipment, museum artifacts, etc.

Base Shear: The total design lateral force or shear at the base of a building structure or nonbuilding structure.

Bending: The curvature of structural or nonstructural components in response to certain types of applied loading. (For example, a beam bends or flexes in response to the weight it supports or to seismic loading).

Cantilever Elements: Elements supported only at the base such as parapets, chimneys, freestanding partitions, or freestanding exterior walls.

Component Importance Factor, I_p : A factor equal to 1.0 for standard installations or 1.5 used for the design of Designated Seismic Systems that are required for post-earthquake life safety or for the continued operations of essential facilities; defined in ASCE/SEI 7-10 Section 13.1.3. Note that this is not the same as the Importance Factor, I_c , assigned for the building structure as a whole.

Consequential Damage: Essential components, such as designated seismic systems, must be protected from damage which might result from the failure of adjacent or connected elements. Thus both the functional and physical interrelationships of essential or nonessential components with essential components must be considered in order to properly safeguard the essential components.

Construction Documents: The written, graphic, electronic, or pictorial documents describing the design, locations, physical characteristics of a project. These documents are typically required to communicate the design intent to contractors and installers and may also be required to demonstrate compliance with applicable building codes or meet specific requirements of the jurisdiction where a project is located.

Construction Observation: The visual observation by a licensed design professional to determine that the elements of the project are constructed in general conformance with the construction documents. The architect, mechanical engineer, structural engineer, etc. may each have an independent duty to perform construction observation. This type of observation is distinct from special inspection.

Damper: Mechanical devices used to dissipate energy and reduce seismic displacements. Dampers come in many shapes and sizes and may be viscous, viscoelastic, lead extrusion, friction, plate yielding, shape memory, or unbonded braces.

Deformability: The ease with which a component deforms under seismic loading. Per ASCE/SEI 7-10, different design parameters are used for high-, limited-, and low-deformability elements and attachments. For example, a high-deformability element is one whose ultimate

deformation is not less than 3.5 times the limit deformation (see ASCE/SEI 7-10 for clarification of these terms).

Design Force: The earthquake forces used for design typically expressed as a percentage of the acceleration of gravity such as 0.3g or 1.0g. Minimum code specified design forces for nonstructural components are found in ASCE/SEI 7-10 Chapter 13 or in the appropriate Building Code in effect where the Project is located.

Design Spectral Response Acceleration Parameters: S_{DS} and S_{D1} are two parameters used in ASCE/SEI 7-10 to characterize the intensity of the ground motion and determine the Seismic Design Category. S_{DS} refers to the 5% damped spectral response acceleration at short periods; S_{D1} refers to the spectral response acceleration at a period of 1 second.

Designated Seismic Systems: This term is applied to those architectural, electrical and mechanical systems or their components that require design in accordance with ASCE/SEI 7-10 Chapter 13 and for which the component importance factor, I_p , is greater than one. This includes systems required to function for life safety purposes after an earthquake including sprinkler systems and egress stairways; components used to convey, support or contain toxic, highly toxic, or explosive substances or hazardous materials; or components needed for continued operation of essential facilities.

Distortion: The change in the configuration of an object or building as it bends or twists out of shape in response to earthquake loading.

Drift: The horizontal displacement of a building resulting from the application of lateral forces, usually forces from earthquake or wind. See also interstory drift.

Earthquake Shaking: The vibratory movement of the earth's crust caused by seismic activity.

Egress, Emergency Egress: Path provided for safe exit from a building in case of emergency. Extra care may be warranted in designing restraints or anchorage for nonstructural components along emergency egress routes and may be required for essential facilities in some jurisdictions. Exit doors, partitions, ceilings, glazing, lighting and piping along the egress route may need special details; furniture and cabinets should be removed or anchored.

Egress Stairways: Stairways required for life-safety purposes in an emergency may be considered designated seismic systems and require special design treatment per ASCE/SEI 7-10 Chapter 13. This requirement may apply to partitions, infill, lighting, piping, etc. in the stairway as well as to the structural supports for stairs that are not part of the building structure.

Essential Facility: Occupancy Category IV facility such as hospital, emergency call center, fire station, emergency shelter as defined in ASCE/SEI 7-10.

Expansion Joint: A separation joint provided to allow for thermal expansion and contraction.

Flexible Connection: The anchorage of an object to a structural member or braced nonstructural component, usually using hardware such as springs, cables, or corrugated tubing, which is designed to allow the object to move relative to the structural member or braced nonstructural component without degradation of performance. Also used to describe connections of pipe or duct to fixed equipment that allows for relative movement; for example, flexible hose connections are advisable for all gas-fired equipment.

Flexible Nonstructural Component: Per ASCE/SEI 7-10, these are nonstructural components with a fundamental period greater than 0.6 seconds. The fundamental period of the nonstructural component (including its supports and attachment to the structure) may be computed per Section 13.6.2 of ASCE 7-10. The design parameters for nonstructural components may depend on whether an item is rigid or flexible.

Foundation: That part of a structure which serves to transmit vertical and lateral forces from the superstructure of a building to the ground.

Frame: A type of structural system in which the loads are carried by a grid or framework of beams and columns, rather than by load-bearing walls. Special purpose frames built up from struts or steel shapes are used to support many types of nonstructural components such as piping, ducts, etc.

Friction Clip: A mechanical device that relies on friction to resist applied loads in one or more directions to anchor a nonstructural component. Friction is applied mechanically and is not due to the frictional resistance produced by the effects of gravity. For Seismic Design Categories D, E and F, friction clips may not be used to support sustained loads in addition to resisting seismic forces.

Hazardous Contents: A material that is highly toxic or potentially explosive and in sufficient quantity to pose a significant life-safety threat to the general public if an uncontrolled release were to occur. (See also IBC 2009 Chapter 4).

Importance Factor, I_c : Per ASCE/SEI 7-10 Section 11.5-1 and Table 1.5-2, the factor applies to the building structure. This factor is distinct from the Component Importance Factor, I_p .

Inertial Forces: Forces necessary to overcome the tendency for a body at rest to stay at rest or for a body in motion to stay in motion.

Inspection Body: Organization or individual accredited to ISO 17020 and regularly engaged in factory inspection services for seismic restraint of nonstructural components and equipment.

Intensity: See Shaking intensity.

Interstory Drift: The horizontal displacement that occurs over the height of one story of a building resulting from the application of lateral forces, usually forces from earthquake or wind. This is often expressed as an interstory ratio; the ratio of the displacement to the height of the story. Interstory drifts from the structural design of a building are often needed in design calculations for nonstructural components such as glazing, pipe risers or precast panels that are attached to more than one floor.

Lateral Force Resisting System: The elements of a structure that resist horizontal forces. These structural elements are typically frames, braces or shear walls.

Magnitude: A measure of earthquake size which describes the amount of energy released.

Mitigation: An action taken to reduce the consequences of a future earthquake. Other terms such as retrofit, rehabilitation or upgrade are also used to describe these actions.

Moment: The moment of a force about a given point, typically referred to as "the moment", is the turning effect, measured by the product of the force and its perpendicular distance from the point.

Nonbuilding Structures: These are self-supporting structures and other structures governed by the design provisions in ASCE/SEI 7-10 Chapter 15. There is some overlap between the definitions for large nonstructural components and nonbuilding structures; it is recommended to check both provisions to see which apply for large or industrial items. Storage racks, tanks, signs, and chimneys are examples of items that may be covered in either Chapter 13 or 15 depending upon the size and support conditions.

Nonstructural Component: Any architectural element; mechanical, electrical, plumbing (MEP) equipment or systems or part thereof; any furniture, fixtures, equipment (FF&E) or building contents. This term is used to describe any and all components within or without a building or nonbuilding structure which are not an explicit part of the structural system. The seismic design of nonstructural components is governed by provisions in ASCE/SEI 7-10 Chapter 13.

Some large nonstructural components may qualify as nonbuilding structures (see ASCE/SEI 7–10 Chapter 15).

Risk Category: A category used to determine structural and nonstructural design requirements in ASCE/SEI 7–10 Table 1.5–1 based on a building’s occupancy. Occupancy Category I is used for the buildings and other structures with the lowest risk to human life such as agricultural facilities; Occupancy Category IV is used for essential facilities such as hospitals which may pose a substantial hazard to humans and to the community.

Partition: A nonstructural interior wall used to subdivide interior spaces. Partitions may span horizontally or vertically from support to support; support may be provided by the building structure or secondary framing members. Partitions may be full-height or partial-height, often stopping just above the ceiling level and are typically constructed of steel or wood studs and gypsum board, wood studs and plaster, brick, or concrete masonry unit infill. Glass block and glazed partitions are also in use.

Positive Connection: A means of anchorage between a nonstructural item and a structural member or braced nonstructural component that does not rely on friction to resist the anticipated earthquake forces. Positive connections are typically made using hardware such as bolts, steel angles, or cables rather than C-clamps or thumb screws. Nails, adhesives and toggle bolts typically do not have enough capacity to provide positive connections for the seismic anchorage of nonstructural items.

Post-installed Anchors: Post-installed anchors in concrete or masonry are those which are drilled and placed into existing construction. Post-installed anchors must be prequalified for seismic applications; for instance, post-installed anchors in concrete must be prequalified in accordance with ACI 355.2 or other approved qualification procedure.

Pounding: The impact of two structures during an earthquake. Pounding frequently occurs when the seismic gap between two adjacent wings of a building, or the gap between two neighboring buildings, is insufficient to accommodate the relative lateral movement of both buildings.

Power Actuated Fasteners: Use of power actuated fasteners to resist seismic loading may be restricted depending on the substrate (concrete, steel, masonry, etc.) and the Seismic Design Category. See ASCE/SEI 7–10 Section 13.4.5 for restrictions and exemptions.

Professional Engineer: A professional engineer is one who is legally qualified to practice in the jurisdiction where the Project is located, who is experienced in providing engineering services of the kind indicated, and is registered with the state where the project is located.

Restraint/Bracing: Bracing or anchorage used to limit movement under seismic forces. Cables or rigid elements (struts, pipes, angles, etc) used to resist forces by uniaxial tension or compression. The term “bracing” may also be used to describe design to resist lateral forces through the use of wall or frame elements.

Rigid Connection: The anchorage of an object to a structural member or braced nonstructural component, usually using hardware such as bolts or brackets, which is designed to prohibit the object to move relative to the structural member or braced nonstructural component.

Rigid Nonstructural Component: Per ASCE/SEI 7-10, these are nonstructural components with a fundamental period less than or equal to 0.6 seconds. The fundamental period of the nonstructural component (including its supports and attachment to the structure) may be computed per Section 13.6.2 of ASCE 7-10. The design parameters for nonstructural components may depend on whether an item is rigid or flexible.

Schematic Upgrade Detail: A drawing outlining the basic elements of an upgrade scheme, but lacking dimensions, element sizes, and other specific information necessary for construction. The terms upgrade, retrofit, rehabilitation, and mitigation are often used interchangeably.

Seismic: Of, relating to, or caused by an earthquake.

Seismic Deformations: Drifts, deflections and seismic relative displacements determined in accordance with the applicable seismic requirements of ASCE/SEI 7-10 or the Building Codes currently in effect where the Project is located.

Seismic Design Category: A classification assigned to a building structure based on its risk category or occupancy and the severity of the design earthquake ground motion. See ASCE/SEI 7-10 Table 1.5-1 for the Risk Category; see Section 11.4 for ground motion; see Section 11.6 for Seismic Design Category. Requirements for nonstructural components depend on the Seismic Design Category which ranges from A to F, from A for the lowest seismicity to F for the highest seismicity. Structures rated Seismic Design Category A are exempt from the nonstructural requirements in Chapter 13; structures rated Seismic Design Categories D, E and F have the most stringent requirements for nonstructural components.

Seismic Drift: The horizontal displacement of a building resulting from the application of lateral earthquake forces. See also interstory drift.

Seismic Force: The force that will act on a nonstructural component during an earthquake is the product of its mass and the seismic acceleration.

Seismic Gap or Seismic Joint: The distance between adjacent buildings, or two portions of the same building, which is designed to accommodate relative lateral displacements during an earthquake.

Seismic Risk: The chance of injury, damage, or loss resulting from earthquake activity.

Seismic Stop: A rigidly mounted bumper or snubber used to limit the range of lateral motion of spring-mounted mechanical equipment. See also air gap, snubber, and vibration isolation.

Seismic Upgrade: Improvement of the resistance of a structural or nonstructural component to provide a higher level of safety or resistance to earthquake forces. For nonstructural components, seismic upgrade schemes typically involve the addition of anchorage hardware or braces to attach the nonstructural item to the surrounding structure. In some instances, the nonstructural item may also require internal strengthening.

Separation Joint: The distance between adjacent buildings, or two portions of the same building, which is designed to accommodate relative displacements between the two structures. Seismic gaps and expansion joints are two types of separation joint.

Shaking Intensity: The amount of energy released by an earthquake as measured or experienced at a particular location. Intensity is subjectively measured by the effects of the earthquake on people and structures.

Shear Wall: A wall designed to resist lateral forces parallel to the wall.

Snubber: A device, such as a mechanical or hydraulic shock absorber, used to absorb the energy of sudden impulses or shocks in machinery or structures. Snubbers are often used to brace pipe runs where thermal expansion and contraction is an important consideration. Snubbers are also required for many equipment items mounted on vibration isolators in order to limit the seismic movement. See also vibration isolation and air gap.

Special Inspection: The observation of work by a Special Inspector or Inspection Body to determine compliance with the approved construction documents and the standards of the authority having jurisdiction over the project. Continuous special inspection requires full-time observation by a special inspector who is present in the area where work is being performed. Periodic special inspection may be part-time or intermittent observation by a special inspector

who is present in the area where the work has been or is being performed. Requirements for continuous or periodic special inspection are typically specified by the jurisdiction.

Special Inspector: An International Accreditation Service (IAS) accredited International Building Code (IBC) special inspection agency or qualified professional engineer who demonstrates competence, to the satisfaction of the building official, for inspection of the designated seismic systems. The owner or the registered design professional in responsible charge acting as the owner's agent shall employ one or more special inspectors to provide periodic inspections during installation of designated seismic systems.

Supports: Those members, assemblies of members or manufactured elements including braces, frames, legs, shear lugs, snubbers, hangers, saddles, struts, and associated fasteners that transmit loads between nonstructural components and their attachments to the structure. Some supports may carry only gravity loads (the weight of the item), such as vertical hangers. Some supports may resist both gravity loads and seismic loads; some may resist only seismic loads.

Upgrade Detail: A drawing presenting the necessary elements of an upgrade scheme, including dimensions, element sizes, and other specific information in sufficient detail so that the drawing can be used for construction.

Veneer: An architectural facing or ornamentation of brick, tile, concrete, stone or similar materials attached to a backing substrate. Veneer may be adhered to the substrate or anchored using mechanical anchors.

Vertical Force Resisting System: The elements of a structure that resist the gravity loads or self-weight.

Vibration Isolation: Mechanical equipment is often placed on specially designed springs to prevent the transmission of mechanical vibrations into the building. Components mounted on vibration isolators also require bumper restraints or snubbers in each horizontal direction to resist seismic loading. The nominal clearance between the snubbers and equipment may affect the seismic design forces; see also snubbers and air gap.

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